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LINK-MOTION

AND

EXPANSION-GEAR,

PRACTICALLY CONSIDERED.

ILLUSTRATED WITH
NINETY PLATES, AND TWO HUNDRED AND TWENTY-NINE WOODCUTS.

BY

N. P. BURGH, ENGINEER.

LONDON:
E. & F. N. SPON, 48, CHARING CROSS.
1870.

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PREFACE.

Of course, as with nearly all my books, when I commenced this one, it was to be two-thirds of its present size at the most, but as I progressed it grew beyond my anticipations, with a corresponding amount of labour; as for example, I found the inventions of valve-gears were so numerous that it involved the process of "winnowing" pretty hard, to blow off the "chaff," which, I need scarcely say, exceeded the "grain" by far: but this was not all, for in many instances the particularities of an invention were so seductively extolled by the inventor, that it was only after close and patient investigation they were discovered to be worthless, and thus kept back from appearing here. In other cases I have been amused at the presumption an inventor fell into with his idea, showing thereby a total blindness of the real requirements. Perhaps the most amusing lesson I learnt was, that the less an inventor knew of what he patented, the more he claimed; while in many cases the same arrangement was patented over and over again with all different claims, or it was one claim embraced all that had been done and more to follow: indeed our Patent Record Library is as amusing a lounge-room as need be for those who will take the trouble to read some of its contents.

From about five hundred examples of valve-gears, patented and not, I selected about one hundred and thirty as being worthy of notice, to appear in the "History of the Practical Application;" added to which I have illustrated over fifty examples of valves; many examples of cam, lever, and crank, motions; starting gears, and other matter; making together more than two hundred and twenty examples, as used from the year 1775 to 1870, or extending over a period of one hundred and five years, arranged in the following order. Adjustable eccentrics and gears, twenty-seven examples. Cams and gears, ten. Cranks, levers, and gears, fourteen. "Corliss" valve-gears, thirteen. Dash-pot and gears, eight. Diagrams, thirty-five. Single eccentrics and gears, eighteen. Expansion gears, twelve. Link motions, fifty-three. Rotary valve-gears, fifteen. Starting and reversing gears, six; and valves, fifty-four examples—being a total of two hundred and sixty-five illustrations.

My letter-press matter has been prepared with care as to the veracity of all the statements relating to the "History." I have the honour also of having brought to light the "History of the Invention of the Link Motion," which appears as the introduction.

Chapter I. explains the Principles of the action of Steam Working Valves.

Chapter II. is the History of the Practical Application of Valve-gearing, commencing at the year 1710, which is the earliest record of the steam engine we have. This is the main portion of the work, for it extends through one hundred and eighty-five pages, and contains one hundred and eighty-six illustrations.

Chapter III. is The Geometrical Principles of the action of Eccentrics and Link Motions, according to their relative positions, as applied for Valve-gears of Steam Engines. I have under that heading fully investigated the actual performances of the eccentrics, links, and valves, under all circumstances in practice; therefore the *suppositions* which are sometimes introduced are carefully avoided, which is saying a *great deal* in literature.

The Rules for the proportions are taken from practice, and have been carefully compiled by me from an active experience of fifteen years.

The plates that are in this work contain more genuine information on this subject than has ever yet appeared; their value also is unequalled as a reference, because each firm who supplied the original drawings sent in their best examples carefully dimensioned and drawn to scale with all the little practical errors which occur during construction faithfully corrected.

Having the confidence of the leading Marine Engineers, I of course have general latitude in my selection of examples of work carried out for illustration in my books; and I trust my readers will be satisfied with my judgment for their benefit in the present case.

On former occasions I have had to confine my thanks to my friends, Messrs. Penn, Langdon, Barclay, Rennie, Field, Humphrys, Dudgeon, Spencer, Ravenhill, and Napier, which are of course repeated now, but extended to the gentlemen whose additional names appear in this work as contributors.

The subjects forming the plates are thus arranged: Beam Engine Valve-Gear, 7 examples; "Corliss" Valve-Gear, 14; Governor Gears and Valves, 3; Marine Expansion Gears, 17; Marine Reversing Gears, 27; Marine Link-Motion, 36; Locomotive Link-Motion, 12; and Geometrical Plates, 10; making 126 examples of Valve-Gearing, &c., practically accomplished, and proved to be worthy of record.

Of my performance in this work, I say nothing, and I leave the result of my labours to the judgment of those who can best appreciate labour honestly discharged.

N. P. BURGH.

78, WATERLOO BRIDGE, LONDON.
JULY, 1870.

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THE

HISTORY OF THE INVENTION OF THE LINK-MOTION.

BY N. P. BURGH.

INTRODUCTION.

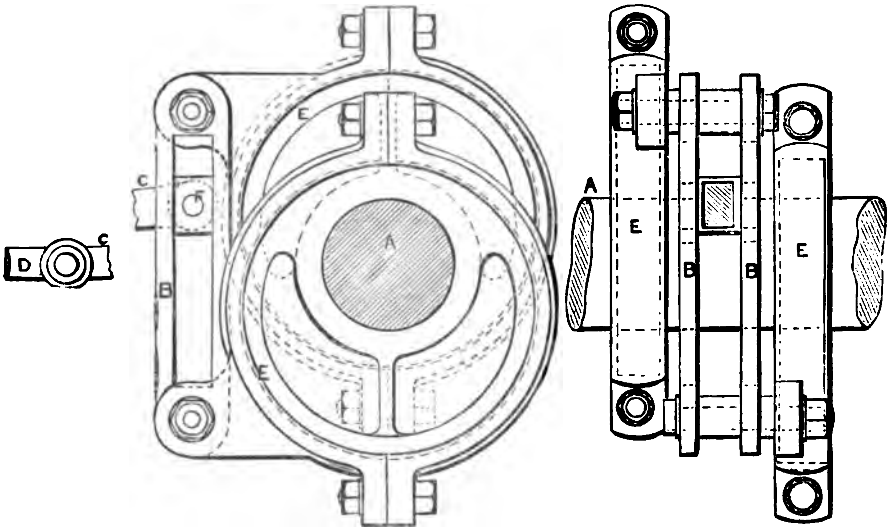
No part of the steam engine demands as much attention as the valve gear, inasmuch that the valve may be all right, but if the gear is imperfect then the proper working of the valve is impossible; and of all the valve gears yet known the original common link motion is not only the most simple but the best also. As a consequence, therefore, the invention of it must have conferred a great benefit on the engineering world, because the locomotive engine, the marine engine, and the reversing, stationary, and portable land engines would in great measure be incomplete and imperfect without it. This is more obvious when it is remembered that the link motion is not only available as a reversing gear, but also as an expansion gear of the most simple and effective order, with the advantage too of regulating the points and limit of cut-off by the valve without any additional detail.

The inventor of the link motion in its simplest, original, and best form is Mr. W. Howe, who introduced it in the month of August, in the year 1842. He was then a working mechanic in the employment of Messrs. Robert Stephenson and Co., engineers, Newcastle-on-Tyne.

The history of the invention may now be given in Mr. Howe's own language, as expressed to the writer:—A species of link motion (shown by Fig. 1 on the next page) was, just before this date, suggested by

Mr. Williams, who was a young gentleman apprentice in the works at the time. This is shown by side and end elevations. A indicates the crank shaft, B the proposed link, C is the connecting rod, connecting the link to the valve rod D; E, E, are the eccentrics, and F the block for reversing the motion of the valve and engine. It will be easily seen that this suggestion could never have been of the least practical use, because one eccentric band would displace the other when in motion.

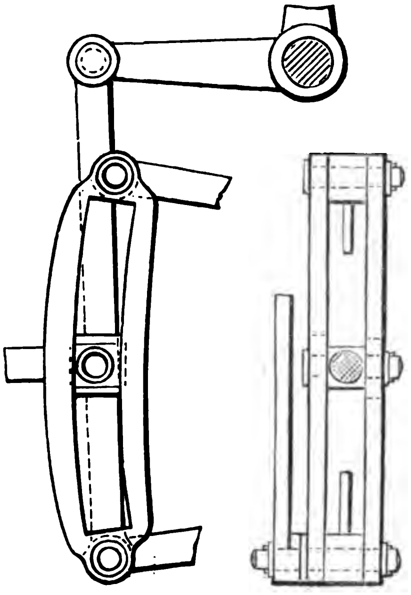
Fig. 1.



Williams's Link-Motion, as suggested by him in the year 1842.

Several persons employed in the works saw this drawing Mr. Williams had made, and amongst them Mr. Howe; but no one brought it into a state for practical application until August, 1842, when Mr. Howe made a pencil sketch and a rough wooden model of his link motion, as represented by Fig. 2 in side and end elevations; and both of the originals can now be seen at the South Kensington Museum. · This model so perfectly indicated what the curved link should be, that, acting upon the advice of his friends, Mr. Howe showed it to Mr. Hutchinson, then the manager of Messrs. Stephenson's works, who at once saw the worth of its application practically, not only as a reversing, but also as an expansion gear for working the slide valve, and he (Mr. Hutchinson) sent the model at once to Mr. Robert Stephenson, then in London, who also approved of it immediately he saw it.

FIG. 2.



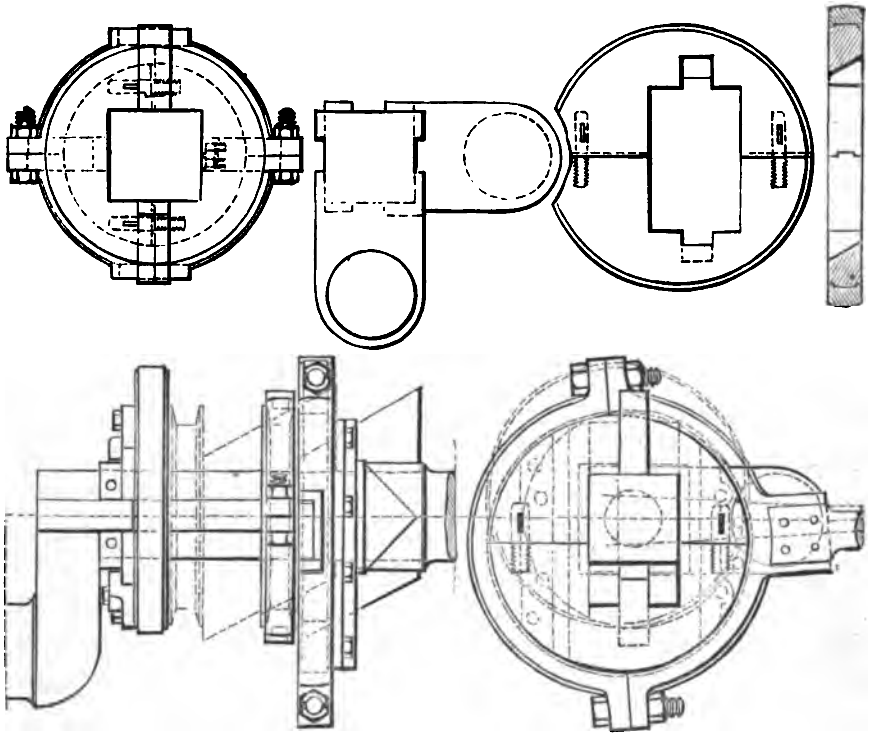
Elevations of the Original Link-Motion invented by W. Howe, in the beginning of the year 1842, while in the employment of Messrs. Robert Stephenson and Co., Newcastle-on-Tyne.

At that time (1842) two locomotives were being made at the works for the North-Midland Railway Company—now a portion of the Midland branches. These engines were to have been fitted with Dodd's wedge motion. Their numbers were 358 and 359 in Messrs. Stephenson's books, but 70 and 71 on the North Midland Railway. One of the locomotives (No. 70) had the wedge motion fitted to it, as shown by Fig. 3 on the next page; but as soon as Mr. Howe brought out the link motion it was put on No. 71 instead of the wedge kind. He was at that time engaged in making a working model of the wedge motion as applied to No. 70, but as soon as he invented his link motion he was instructed to throw the other aside, and make a full-size model of his kind, which he did, and thus fully proved the adaptation of the link motion for any grade of cut-off by the slide valve; and as the model included the sections of the cylinder, piston, and slide valve, the points of cut-off for each stroke of the piston were readily seen. The valve had only $\frac{1}{2}$ inch outside lap, and $\frac{1}{16}$ inch inside lap; the opening caused by the valve for the admission of the steam was 1 inch, making the throw of the eccentric $1\frac{1}{2}$ inch, and the travel of the valve 3 inches; the length of the eccentric rods was 5 feet, and thus the lead was practically constant, as shown by the following table:—

Tabular Statement of the Working of Howe's Link-Motion fitted to No. 71 Locomotive Engine on the North-Midland Railway, constructed in 1842.

Notch.	Valve travel.	Steam port open.	Supply lead.	Cut-off at stroke of piston.	Exhaust port open.	Ratio of expansion.	Ratio of exhaustion.	Exhaustion lead.
	Inches.	Inches.	Inches.	Inches.	Inches.			
1	$2\frac{3}{16}$	$\frac{7}{8}$	$\frac{1}{8}$	$17\frac{1}{8}$	$19\frac{1}{8}$	2	$\frac{7}{8}$	$\frac{9}{16}$
2	$2\frac{1}{2}$	$\frac{3}{4}$	$\frac{1}{8}$	$16\frac{1}{4}$	$18\frac{3}{4}$	$2\frac{1}{2}$	$1\frac{1}{4}$	$\frac{9}{16}$
3	$2\frac{1}{4}$	$\frac{5}{8}$	$\frac{1}{8}$	$14\frac{7}{8}$	$18\frac{1}{8}$	$3\frac{1}{4}$	$1\frac{7}{8}$	$\frac{9}{16}$
4	2	$\frac{1}{2}$	$\frac{1}{8}$	13	$17\frac{1}{8}$	$4\frac{1}{8}$	$2\frac{7}{8}$	$\frac{9}{16}$
5	$1\frac{3}{4}$	$\frac{3}{8}$	$\frac{1}{8}$	$10\frac{3}{8}$	$15\frac{3}{4}$	$5\frac{3}{8}$	$4\frac{1}{4}$	$\frac{9}{16}$
6	$1\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{8}$	$7\frac{3}{4}$	14	$6\frac{5}{8}$	6	$\frac{9}{16}$
7	$1\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{8}$	$4\frac{1}{4}$	$11\frac{1}{2}$	$7\frac{1}{4}$	$8\frac{1}{2}$	$\frac{9}{16}$

FIG. 3.



Elevations and Details of Dodd's Wedge-Motion as fitted to No. 70 Locomotive of the North Midland Railway.

Tabular Statement of the Working of Dodd's Wedge-Motion fitted on No. 70 Locomotive, on the North Midland Railway, in 1842.

Notch.	Valve travel.	Steam port open.	Supply lead.	Cut-off at stroke of piston.	Exhaust port open.	Ratio of expansion.	Ratio of exhaustion.	Exhaustion lead.
	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
1	$3\frac{3}{4}$	$\frac{7}{8}$	$\frac{1}{8}$	$14\frac{1}{2}$	$18\frac{1}{8}$	$3\frac{5}{8}$	$1\frac{7}{8}$	1
2	$3\frac{11}{16}$	$\frac{13}{16}$	$\frac{1}{8}$	$14\frac{1}{8}$	$18\frac{1}{8}$	4	$1\frac{7}{8}$	1
3	$3\frac{1}{2}$	$\frac{3}{4}$	$\frac{1}{8}$	13	$17\frac{7}{8}$	$4\frac{7}{8}$	$2\frac{1}{8}$	1
4	3	$\frac{1}{2}$	$\frac{1}{8}$	11	$16\frac{7}{8}$	$5\frac{7}{8}$	$3\frac{1}{8}$	1
5	$2\frac{9}{16}$	$\frac{1}{4}$	$\frac{1}{8}$	$7\frac{1}{2}$	$15\frac{1}{2}$	8	$4\frac{1}{2}$	1
6	$2\frac{1}{4}$	$\frac{1}{8}$	$\frac{1}{8}$	$3\frac{1}{4}$	$12\frac{1}{4}$	9	$7\frac{3}{4}$	1
7	$2\frac{3}{16}$	$\frac{1}{8}$	$\frac{1}{8}$	1	$8\frac{7}{8}$	$7\frac{7}{8}$	$11\frac{1}{8}$	1

Cylinders, 14in. diameter; stroke of piston, 20in.; steam ports, 10in. long and $1\frac{1}{4}$in. wide; outside lap of the slide valve, 1in.; inside lap, $\frac{1}{16}$in., as for No. 71.

The link is represented by Fig 2. in side and end elevations, but its application to the first engine in practice was on September 10th, 1842, as is shown by Fig. 4 in plan and side elevation on the next page.

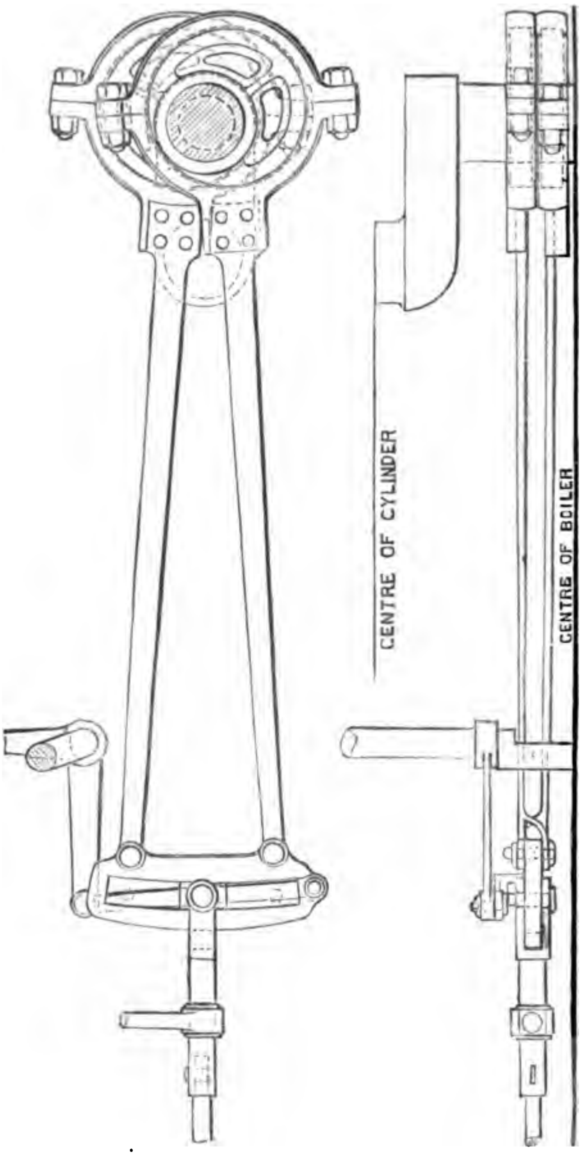
About that time there were divided opinions as to the efficiency of this link motion; but Mr. Robert Stephenson settled the question by adopting it, and acknowledged that Mr. Howe was the inventor also by instructing his cashier to make him a present of twenty guineas for his invention, and afterwards, as a further recognition, appointed him, in 1846, to be engineer of the Stephenson Collieries and Ironworks at Clay Cross, Chesterfield, where he is now.

Being thus placed in a more independent position, Mr. Howe had an opportunity of applying the link motion in many ways to various classes of engines, and in the year 1847 he designed and applied the first link motion to a winding engine with success.

This motion was the twin-solid link-type, as shown by Fig. 5 in plan and side elevation; and Fig. 6 is a side elevation and sectional plan of the same link, as illustrated on page 7.

The illustration, Fig. 7 on page 8, is a plan and side elevation of the

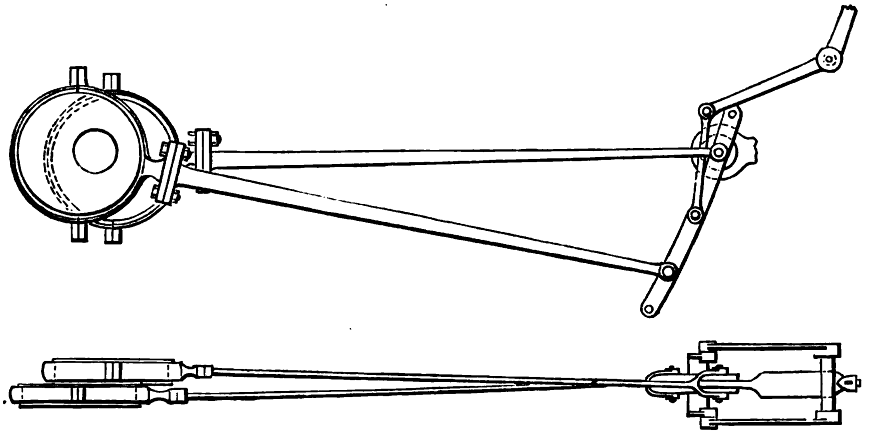
Fig 4.



Elevation and Plan of Howe's Link-Motion as Applied by Messrs Robert Stephenson and Co. in the year 1842.

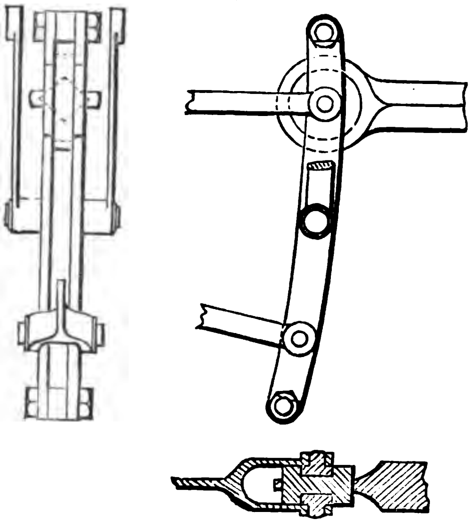
valve gearing and a portion of the winding engine mentioned; and Figs. 8 and 9 illustrate the principal details of the starting gear and link.

Fig. 5.



Arrangement of Howe's Twin Bar-Solid Link-Motion, invented by him, and applied to one of the Winding Engines at Clay Cross Works in the year 1847.

Fig. 6.



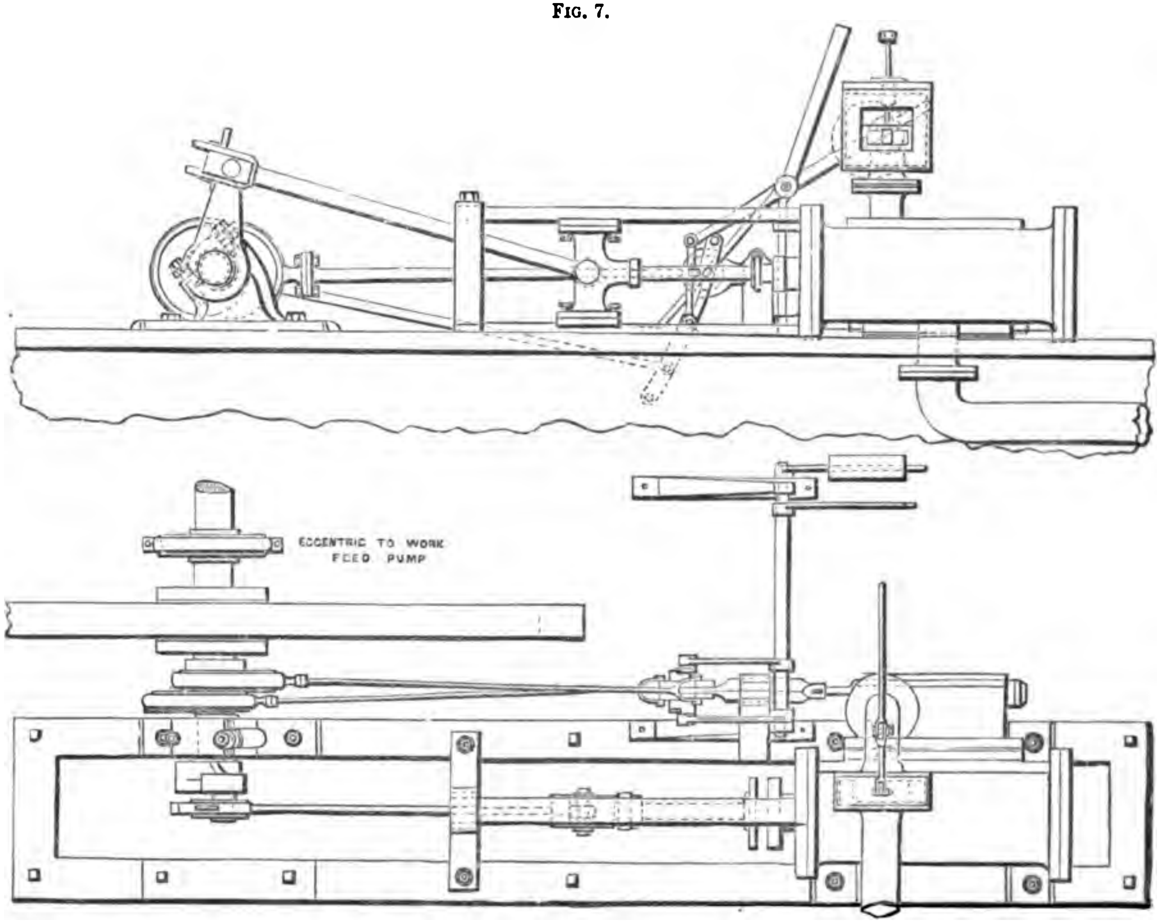
Detailed Views of Howe's Twin "Solid" Link-Motion as shown by Fig. 5.

It should be mentioned here that the vibrating block, enclosing the link that worked in the eye of the valve rod, was made of brass; and the eye of wrought iron was not case-hardened, and as the "wear" was considerable in consequence, the adjustable head for the twin-bar link was invented by W. Howe in the year 1848, as illustrated by Fig. 10 in side elevation and sectional plan on page 11.

The means of adjusting the wearing surface consisted of putting the link block in halves in an ordinary connecting rod head, with the usual strap, gibs, and cotter, so that the halves could be keyed up when required.

A full-sized model link, on this principle, was made, and Fig. 11 on page 12 is a perspective view of it from a photograph since taken, as the

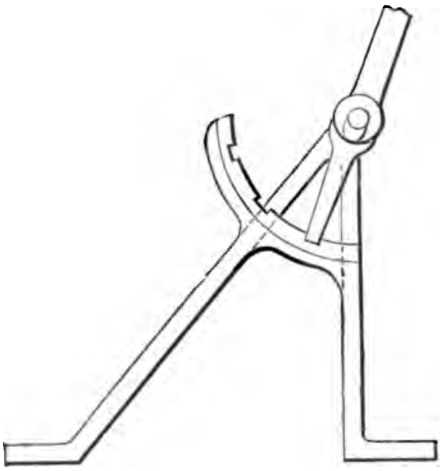
Fig. 7.



Part of the Side Elevation, and Part Plan of the Clay Cross Winding Engine, fitted with the Twin-Bar Solid Link-Motion by William Howe, the Inventor, in the year 1847.

link has been preserved. It was shown to Mr. Robert Stephenson, who highly approved of it, and desired William Howe to send it to the works at Newcastle. On receiving the model there, Mr. Weallens wrote to William Howe, also approving of the mechanical arrangement, and said he had shown it to Mr. Hutchinson, the manager, and Mr. Fletcher, of the North-Eastern Railway, and other men of mechanical science, all of whom agreed with Mr. Stephenson that the improvement was particularly advantageous over the solid block.

Fig. 8.



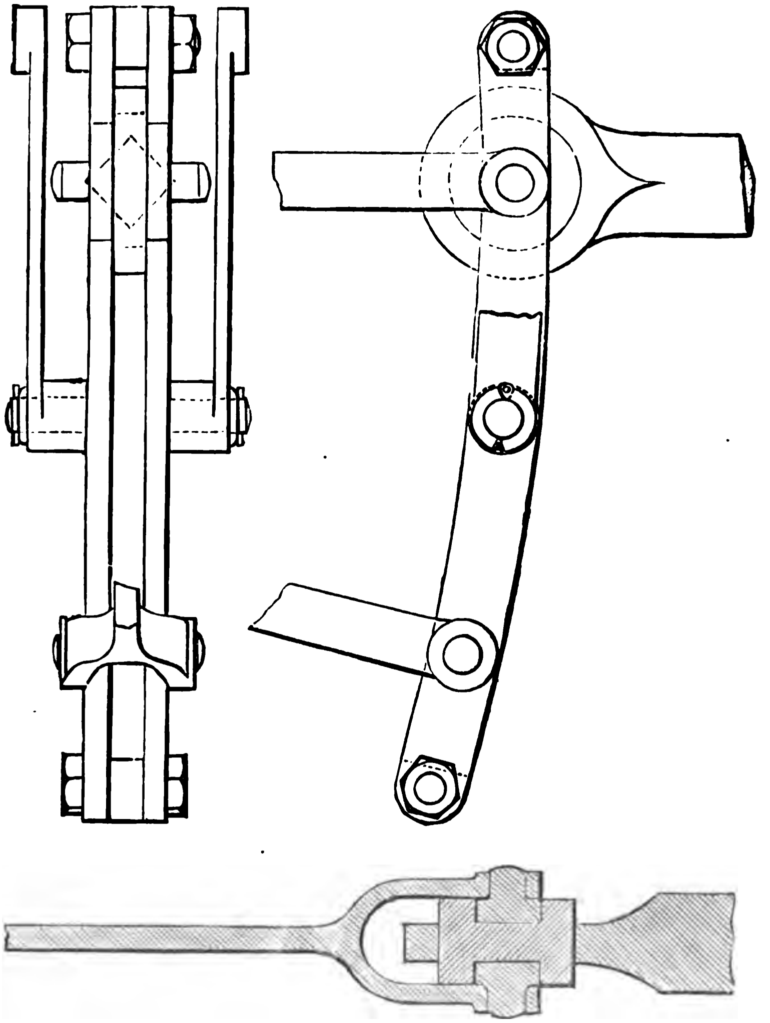
Detail of the Starting Gear of the Engine shown by Fig. 7, scale 1½ = 1 foot.

In the year 1854 Mr. Howe further designed another modification of his solid bar link, as shown by Fig. 12 in end and side elevation and sectional plan on page 13. This was applied to a large winding engine erected at the Clay Cross Works. The cylinder is 36 inches diameter, and 6 feet stroke of piston; it has been in constant work ever since, with perfect satisfaction, without repair or alteration, although the engine has been raising from 300 tons to 800 tons of coals and materials per diem up a shaft more than 200 yards deep.

It became essential in the year 1864 that the Clay Cross Company should extend their works, and it devolved on William Howe, their engineer, to design suitable engines to raise from a depth of 300 yards a certain quantity of coals and materials, for which he designed the arrangement shown by Fig. 13 on page 14, which is a side elevation and plan of a modification of Allan's straight link-motion applied by William Howe with much success.

The working gear of this engine is shown in plan and elevation by Fig. 14 on page 15, to which he applied the principle of Melling's valve gear, as described in this work on page 13, and illustrated by Fig. 10 on page 12. The eccentrics are fixed on a counter shaft that is driven by a pin passing through a drag link, receiving its motion from the connecting

FIG. 9.

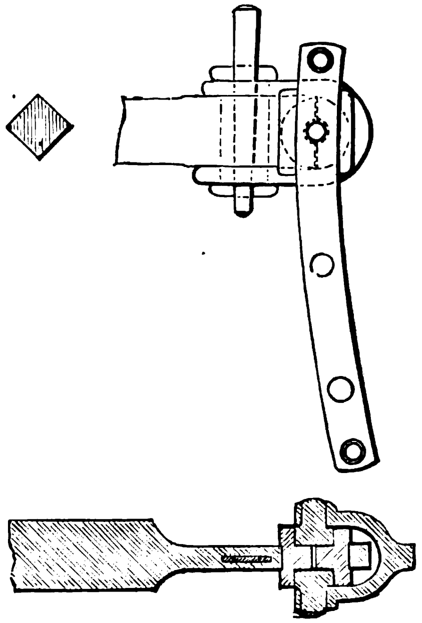


Details of the Link-Motion of the Engine shown by Fig. 7, scale 3 in. = 1 foot.

rod *b*. *a* indicates the crank shaft on which the drum, 15 feet in diameter, is fixed; *b* is the connecting rod, *c* the counter shaft, *d* the counter crank, *e*, *e* are the eccentrics, *m* the drag link worked by the pin or stud on the connecting rod, situated 4 feet from the main crank pin; *f* is the straight link, and *g* the reversing shaft, *h* the crosshead, *i* the guide rod, *l* the reversing rod leading from the link to the valve rod guide, *k* the piston rod, and *n* is the reversing handle. The cylinders of these engines are 30 inches in diameter with a piston stroke of 5 feet, the valves are the ordinary balanced slide valves, with ½ inch outside lap; the area of the full supply steam opening being $\frac{1}{18}$ of that of the cylinder, and the engines with the gear referred to were under perfect control when raising 36 cwt. of coal 300 yards in thirty-five seconds.

Subsequently to the erection of those engines, William Howe applied the same arrangements of valve gearing to another engine at the Coton Bank Collieries, near Burton-on-Trent, and since that to a similar pair of engines at the Clay Cross Works, the only difference being that the valves of the latter engines have 1 inch outside lap, which is more economical for the use of the steam, but is not so powerful in speed; and the high speed is of more importance with winding engines than a slight saving of fuel.

Fig. 10.

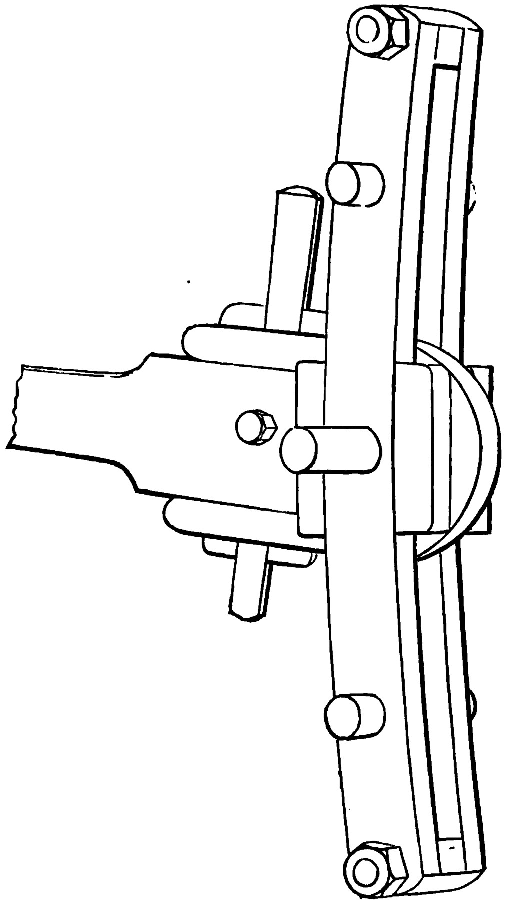


Adjustable Head and Block for the Twin-Bar Link-Motion, invented by William Howe in 1848.

It is now undoubtedly proved that Mr. Howe not only invented the common link-motion, but also that he improved his original ideas to a considerable extent at an early period; and also that to the engineering world he conferred a lasting benefit, where the steam-engine is used. That he fully understands the principles of his invention will be understood from the diagrams on page 16, which he has sent the author.

Figs. 15 and 16 are skeleton diagrams of a link-motion, slide valve, crank, and pin, showing an equal lead for the slide valve at each end of the piston stroke. Figs. 17 and 18 illustrate the relative angles of the eccentric rods and positions of the valve for reverse positions of the crank when the link is midway suspended. Figs. 19, 20, 21, and 22, refer consecutively to Figs. 15, 16, 17, and 18, when the eccentric rods

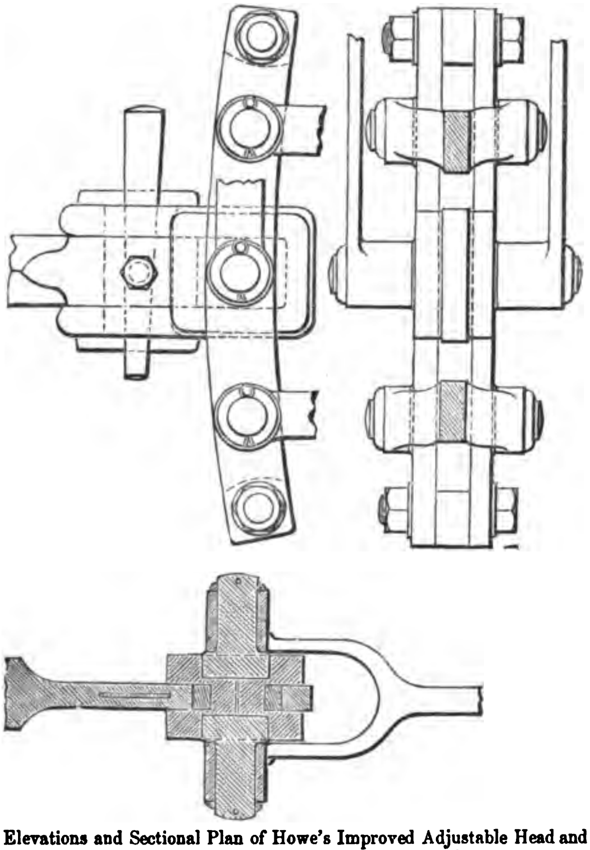
FIG. 11.



Perspective View of Howe's Adjustable Head Block for Twin Solid Bar Link-Motion, made in 1848.

are not crossed in the first case, and the crank rising, but in the second are crossed and the crank working downwards, the angles of the eccentrics being the same in each case. It may be added that the alteration of lead in both instances is reduced as the length of the eccentric rod is increased, and *vice versâ;* a fact that must always be considered with the link motion.

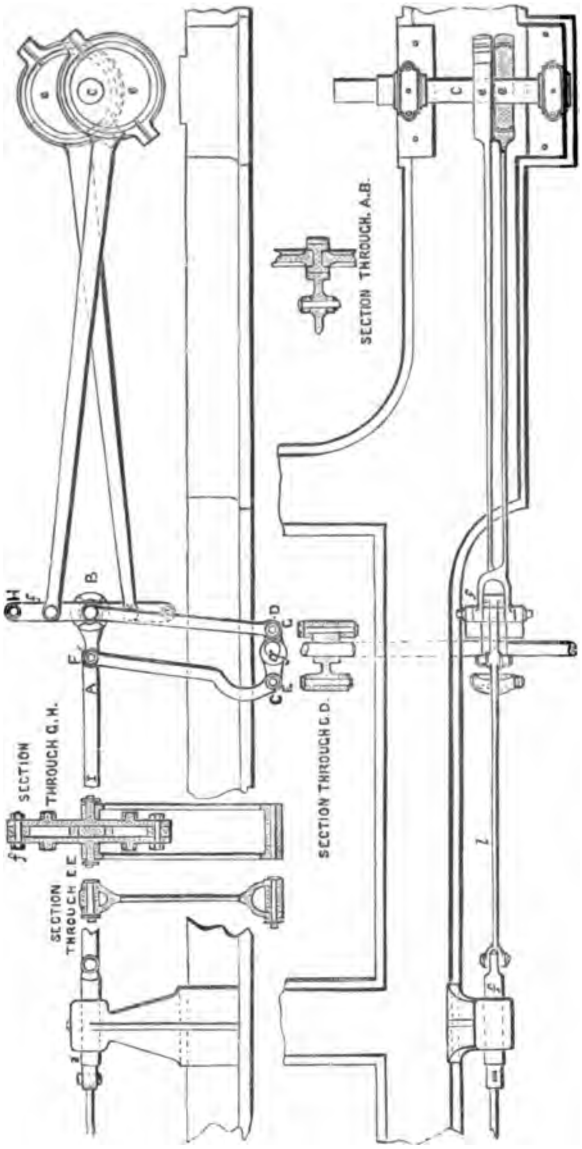
FIG. 12.



Elevations and Sectional Plan of Howe's Improved Adjustable Head and Block, Link-Motion, applied to a Winding Engine in the year 1854.

This motion has been used since the year 1842 by all makers of steam engines for locomotive, marine, and stationary purposes, of all classes and sizes, which, without it, could not have been so successful as they have, for there is no other valve gear its equal, even now;

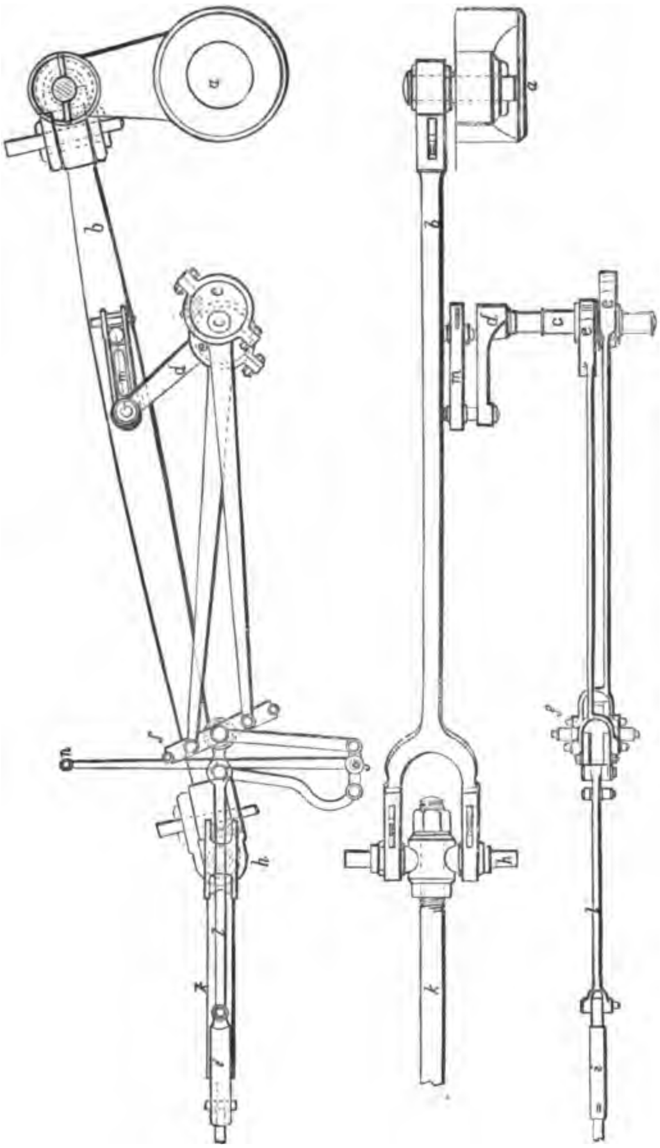
Fig. 13.



Arrangement of Allan's Straight Link-Motion, applied by William Howe to a Winding Engine, in the year 1864, at the Clay Cross Works.

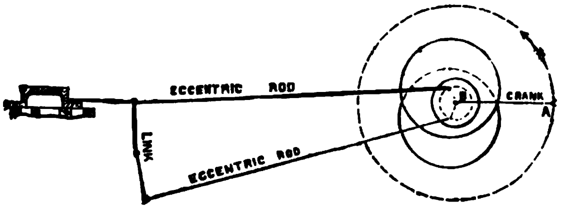
although, as we shall show in the second chapter, that divers inventions before and since have been proposed, patented, constructed, and applied for the very object of dispensing with it, if possible.

Fig. 14.



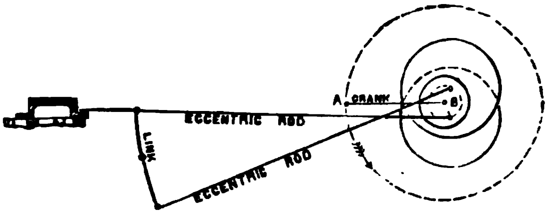
Working Gear of the Link-Motion shown by Fig. 13.

FIG. 15.



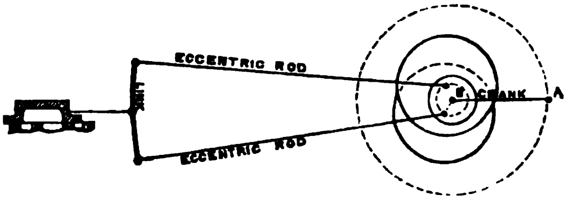
Howe's Skeleton Diagram of Link-Motion when the Link is down and the Crank out from the Valve; when the latter gives lead for the Steam.

FIG. 16.



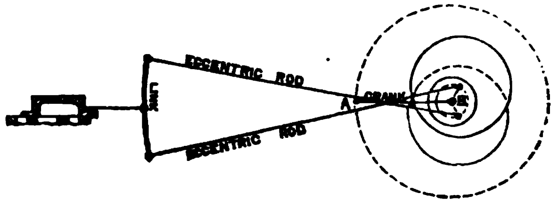
Howe's Skeleton Diagram of Link-Motion when the Link is down and the Crank is in towards the Valve; when the latter gives lead for the Steam.

FIG. 17.



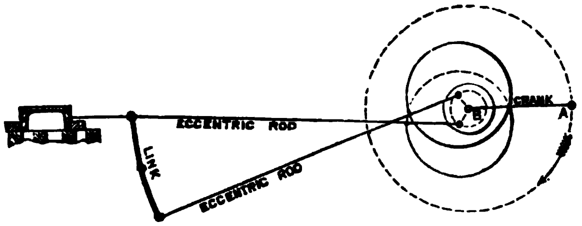
Howe's Skeleton Diagram of Link-Motion when the Link is midway and the Crank out from the Valve.

FIG. 18.



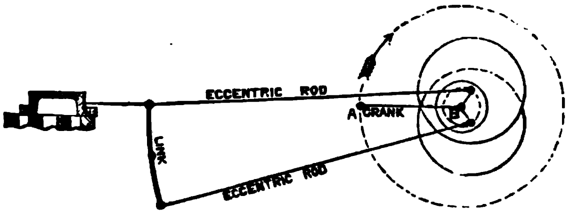
Howe's Skeleton Diagram of Link-Motion when the Link is midway and the Crank in towards the Valve.

FIG. 19.



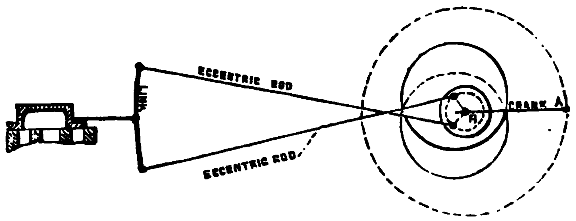
Howe's Diagram, showing the Eccentric Rods crossed, instead of as in Fig. 15, but the position of the Crank and the Lead being, as before, with the Link down.

FIG. 20.



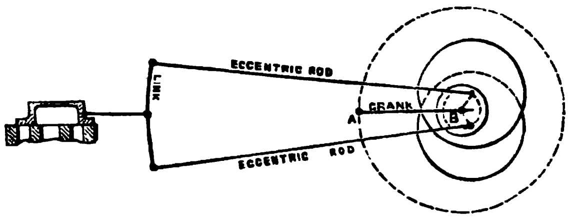
Howe's Diagram, showing the Eccentric Rods not crossed, instead of as in Fig. 16, but the position of the Crank and the Lead being, as before, with the Link down.

FIG. 21.



Howe's Diagram, showing the Eccentric Rods crossed, instead of as in Fig. 17, the position of the Link and Crank being as before, but no admission of Steam by the Valve.

FIG. 22.



Howe's Diagram, showing the Eccentric Rods not crossed, instead of as in Fig. 18, the position of the Link and Crank being as before, but no admission of Steam by the Valve.

LINK-MOTION

AND

EXPANSION-GEAR.

CHAPTER I.

THE PRINCIPLES OF THE ACTION OF STEAM-WORKING VALVES.

THE regulation of steam, in its application as a motive power, is of the utmost importance; and it is for that reason that all engineers who design and construct steam-valves and their motion-gear, should consider first the requirements that are subject to the purpose, and secondly, the *most* simple and effectual mechanical arrangement possible that can develop them. In order, therefore, to probe this matter properly, we must dilate first on the principles of the requirements, and after that discuss the means for the mechanical development.

The action of the steam in an engine-cylinder is designated under four headings, known as "lead, cut-off, expansion, and exhaustion," which are the principles of the requirements on which the arrangement of the valve and gear depends.

LEAD.—This is practically a certain quantity of steam that is admitted between the piston and the cylinder end, when the former is moving towards the latter, and thereby checks the momentum of the piston at each end of its stroke or travel, and prevents it from straining the piston and connecting rods, and disturbing the centres of the true positions of the crank-pin and shaft. The position of the valve to cause lead, is that it uncovers the steam-port, or opens the passage for the admission of the steam into the cylinder, before the piston completes its travel or stroke. So that the situation of the valve relative to its travel is said to be in advance of that of the piston under the same circumstance of relation. The valve, therefore, has performed the greatest portion of its limit of motion in one direction before the piston has commenced the similar movement. Now the *time* allowed for lead will depend on the advance position of the valve, and as time is subjected to motion in this case, the relation of one to the other must be constant; therefore, if we have lead for a high-speed engine, and the valve-gear is arranged for that purpose, we shall have the lead constant with a lesser speed, because—although time is subject to valve-speed—travel is subject to gear-motion, and if the lead is required to be altering with the speed, then the gear must be in connection with the engine-governor.

CUT-OFF.—The quantity of steam that is admitted during the limits of lead and cut-off is the "supply;" hence it is evident that the amount of supply is subject to the time allowed between the lead and cut-off, for the admission of the steam.

Now let us put this matter graphically, for the purpose of demonstrating the actual meaning of the facts in practice. Suppose we are looking at an engine-cylinder, and can see the internal details in it, we notice that when the piston has reached *nearly* to the end of the cylinder, steam is admitted into it by the valve, and thus the speed of the piston is checked, and when it has reached to the end of its travel, a certain quantity of steam is lodged between the piston and the cylinder end, which acts as a spring, or as it is often termed, "*cushion*."

The piston is now seen to return and go back again, and immediately it moves the steam rushes in after it, and indeed impels it along, so that *the more time there is allowed for supply the greater power is in the engine.* But at a certain point of the piston's travel the steam is "cut off," and thus the supply is stopped. Now the main question here is; how the steam was cut off; whether slowly, by a gradual motion of the valve, or suddenly, by a quick motion. Suppose it were slowly, let us watch the action. When the piston had moved for a certain distance from the end of its travel, the area of the supply opening began to be decreased by the valve passing slowly over the port, and continually decreasing its opening until the port was covered by the valve. Now the powerful effect of steam is in direct proportion to its quantity—pressure being excepted—and, therefore, when the valve began to reduce the area of the steam supply opening, the power was reduced from that moment, and gradually reducing also to the time of cut-off, so that with a gradual cut-off, the efficiency of the steam is lessened *from the beginning* of the action of cut-off to the stoppage of the admission.

Let us now watch the action with a sudden cut-off. The piston is advancing as before from the end of the stroke, the supply of the steam being constant and the quantity in the cylinder increasing; at a certain point the valve closes at once, the admission of steam is stopped, but as the supply was equal during the beginning of the motion of the piston to the point of cut-off, the power was equal also, and therefore no reduction ensued, as with the slow motion for the valve.

EXPANSION.—The steam that has been admitted into the cylinder is now supposed to be cut-off from that proceeding from the boiler, and our attention must be directed next to what it performs; for it is now a power without any assistance whatever, and indeed so self-reliant that all the energy it expends diminishes the original possessive power proportionately. This reduction of power is due to the piston being impelled by the *expansive* action of the steam situated between the cylinder end and the piston—including that in the steam passages leading to the valve.

Here then we have a volume of steam exerting *all* its efforts to burst the cylinder, and as it does not do that, it pushes the piston onwards, but without any assistance whatever from the steam that is in the boiler; hence the power of the engine for a period, originates from the *elasticity* of the steam, the action of which in the cylinder is practically as a steel spring that has been compressed, and on releasing it, all the power—excepting that absorbed by friction—that has compressed it, is given out again by the spring's exertion to expand itself to its natural limit of extension.

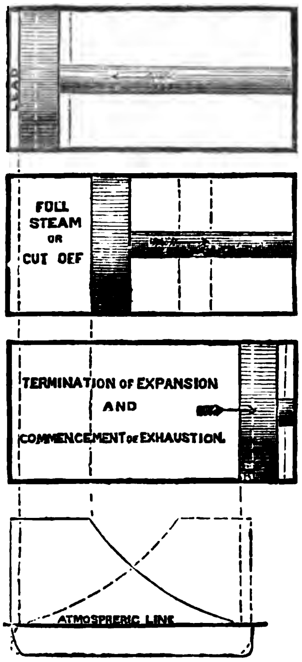
This is an analogous definition of the expansion of steam, and our next purpose is to describe how the original power is reduced proportionately to the limit of expansion. The reduction of the original power of the steam by expansion is due to one cause theoretically, but to two practically, in this way: the steam is said to be reduced theoretically in pressure, or power, proportionate to its cubical expansion; as for example, suppose a volume of steam at 60 lbs. per square inch pressure occupied *one* cubic foot, and it is permitted to expand into *two* cubic feet, the pressure will be reduced to 30 lbs., and so on in a similar proportion; but in practice this reduction of pressure is more than quoted; and the two practical causes alluded to are radiation and friction of the steam that produce it, so that the loss in practice below theory is equal to from 10 to 15 per cent. The friction is constant due to the pressure, but the radiation is less or more as the cylinder casings and steam supply pipes are covered or not.

EXHAUSTION.—The steam is now presumed to have performed all its duty in the cylinder, and is being released to expand into the atmosphere or be condensed into its normal condition in the condenser. The action of the exhaustion should be as quick as possible, but unless the slide valve and ports are suitably arranged, the process is checked or slowest at the commencement instead of being the quickest; in fact, the principle of exhaustion is that the piston shall be relieved from the pressure of the steam in front of it before it returns back again to the end of the cylinder.

Suppose now, for the purpose of instruction, we resume our graphic description of the use of steam from the commencement to the completion of its duty under the heading of—

ACTION OF ONE VOLUME OF THE STEAM DURING ONE HALF THE REVOLUTION OF THE CRANK-PIN.—The piston is at one end of the cylinder; the valve has sufficiently uncovered the supply-port for "lead;" the connecting rod and crank are on the same line of position; the crank-pin rises; the piston moves; in rushes the steam after it, and continues to fill the space in the cylinder with equal pressure until the valve suddenly closes the port; "the cut-off" here occurs and also at this point "expansion" begins. The piston is now, say at one one-third of its travel, and the crank and connecting-rod at the relative angles. The steam drives the piston before it, and as the crank-pin is now traversing the portion of its travel that is most coincident with that of the piston, the momentum is at its utmost limit of power. At, say about seven-eighths of the piston's travel, the valve uncovers the exhaust port; away rushes the steam from its duty in the cylinder and leaves the piston to itself; and here happily the momentum left in the crank-pin is transmitted to the piston, which carries it on to the end of the stroke. The crank and connecting rod are now on the level line again in the opposite direction to that before; and the "lead" occurs again also at the opposite end of the cylinder.

Fig. 1.



Diagrams of the positions of the piston of an engine, at occurrence of "lead, cut-off, expansion, and exhaustion," with the corresponding indicator diagrams.

The principles of the correct method of regulating the use of the steam in engines is therefore *ample* "lead" in proportion to the speed of the piston; *instantaneous* "cut-off;" *maximum* "expansion;" and *immediately total* "exhaustion" during each stroke of the piston. To make this matter perfectly understood we illustrate by Fig. 1 the limits of the inside lines of a cylinder, with the piston in three positions, and an indicator diagram whose limits agree with them. The return positions are shown by dotted lines, also the relative indicator diagram. These diagrams are *perfect*, and demonstrate a similar arrangement of gear and valves; this is theory, however, and we will now turn to the practice and see the width of the disagreement.

CHAPTER II.

THE HISTORY OF THE PRACTICAL APPLICATION OF VALVE-GEARING.

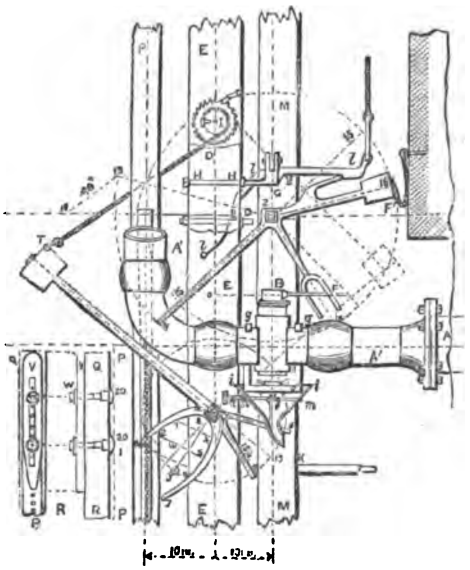
THE most reliable history of the original adoption of valve-gear in steam engines has been written by a Doctor Desaguliers, who not only was an eminent philosopher, but also a practical machinist, and in his courses of " Experimental Philosophy," dated 1744, he states :—

"About the year 1710, Thomas Newcomen, ironmonger, and John Cawley, glazier, of Dartmouth, in the county of Southampton, made then several experiments with the steam-engine in private, and having brought it to work with a piston, &c., in the latter end of the year 1711, made proposals to draw the water at Griff in Warwickshire; but their invention meeting with no reception, in March following, through the acquaintance of Mr. Potter of Bromsgrove, in Worcestershire, they bargained to draw water for Mr. Back of Wolverhampton, where, after a great many laborious attempts, they did make their engine work. They were at a loss about the pumps, but being so near Birmingham, and having the assistance of so many admirable and ingenious workmen, they soon came to the method of making the *pump-valves, clacks, and buckets;* whereas they had but an imperfect notion of them before. One thing is very remarkable. At first working, they were surprised to see the engine go several strokes and very quick together, when, after a search, they found a hole in the piston which *let the cold water in to condense the steam in the inside of the cylinder,* whereas, before, they had always done it on the outside. They used before to work with a buoy in the cylinder inclosed in a pipe, which buoy rose when the steam was strong, and opened the injection-pipe and made a stroke, whereby they were capable of only giving six, eight, or ten strokes in a minute, till a boy named Humphrey Potter, who attended the engine, added what he called *scoggan, by which the beam of the engine always opened and shut its own valves,* and then it would go—entirely without the attendance of a man—fifteen or sixteen strokes in a minute. But this being perplexed with catches and strings, Mr Henry Beighton, in an engine he had built at Newcastle-on-Tyne in 1718, took them all away, *the beam itself supplying all much better.*"

So that from that date self-acting valve-gear for steam-engines was adopted, and, although in a crude state, performed its duty with precision sufficient enough to be adopted for regulating the supply of the injection-water also; and consisted of an arrangement of levers and catches that opened the steam-valves and injection-cock by the levers being raised and lowered by tappets on the working-rod, which was descending or hung from the beam of the engine. The entire affair was of course of the primitive order, and therefore very defective.

In the year 1769, Mr. Smeaton made a beam, single acting, steam-engine with the valve-gear arranged pretty much as Beighton's, and in the year 1775 another engine with improved valve-gear, which we illustrate by Fig. 2, the description of which is as follows :—

FIG. 2.



Front elevation of Smeaton's Valve-gear for his single-acting Steam Beam-Engine of 150 nominal horse-power, made in the year 1775.

"A is the lower corner of the

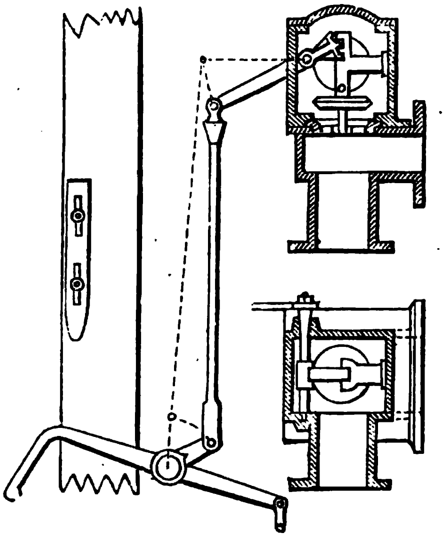
cylinder, A A′ A′, the injection-pipe, B, the injection-cock, B F, its handle or spanner passing between the forks of the bent lever E Z F F′, called the F lever, by which the cock is opened and shut. The tail Z 12 of this F lever is, by the downward motion of the plug-tree P, forced from the position shown by the dotted line Z 18, into the position in which it is seen in the drawing, and it is there retained by the catch *l l l*. While the lever is in this position the injection-cock is shut, the steam from the boiler is flowing into the cylinder, and the piston is rising. When the piston has nearly reached the top of its course, an apparatus attached to the plug-frame P, draws up the catch *l l l*, and releases the F lever, which is forced into the position 18 Z, by the bob or weight 16, carried by its end F′, and the consequent movement of its fork F opens the injection-cock; T *x* 11, 9, is the Y lever or tumbler, which acts upon the stirrup rod *k* attached to the spanner of the regulator, as in Beighton's gear. The range of the tumbler's motion on each side of the perpendicular is regulated by its check-cord T I, which is passed round a roller I, furnished with a paul and ratchet, so that its length may be adjusted. The tumbler is moved by pins in the plug-frame P, acting upon its bent arms *x* 3, *x* 7.

"In the left-hand corner at the bottom of the illustration is seen a representation of a slider, which may be fixed upon the plug-tree instead of the pins, to work the lever. There is both a side and a front view of the slider. Q R shows a part of the plug-tree, V the slider, and W 20 20 two screws for retaining the slider in its place. By this means the working-stroke may be adjusted much more surely than by the pins or plugs.

"The working of the injection-cock by the forked end of the F lever was found to be defective, and Mr. Smeaton, in the engines which he afterwards constructed, fixed a toothed sector on the end of the lever, which was made to act upon a toothed wheel, carried by the axis of the injection-cock, somewhat in the manner of the parts of Beighton's gear already mentioned."

The memorable James Watt, in the year 1788, made a vast improvement on Smeaton's engine, by making it double-acting, and the valve-gear is shown by Fig. 3, which is a drawing of one of the valves and its working gear, also a part of the air-pump rod, formed of wood, called the plug-frame or plug-tree, on which are two projecting plugs of wood to work the upper and lower valves. As the plug-tree moves up and down, the plugs strike the handles or working gear of the valves, and open or shut them at the proper instant. The valves are called conical valves, because the small cover which closes the opening of each nozzle under the valve is slightly tapered downwards so as the more readily to fit its seat, and each is lifted from its seat by a small toothed rack and pinion moved by a spindle from without, communicating by rods with the valve gear. When the plug-frame descends, the valve is closed by the plug, and the valve is shut.

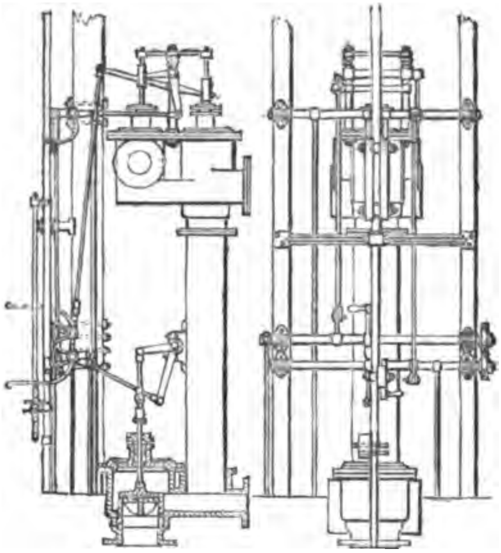
FIG. 3.



Side elevation of Watt's Valve-gear, and sections of Valve and Seating for his double-acting Steam Beam-Engine, made in the year 1788.

Mr. Murdock, Mr. Watt's assistant, very much improved the valve-gear for beam steam-engines—over Mr. Watt's arrangement as shown by Fig. 3, above—and the result of his labours was the now well-known "Cornish" valve-gear, as shown in side and end elevations by Fig. 4, which was introduced as far back as 1820, and of course has been improved in detail since, which we shall notice, but the main portion is even now as at the date mentioned. Soon after that time the vertical direct acting engine came into use, and with it the cam and eccentric motion for working the *slide* valve. Next was introduced the horizontal engine, with the valve-gear of the former applied for the same purpose.

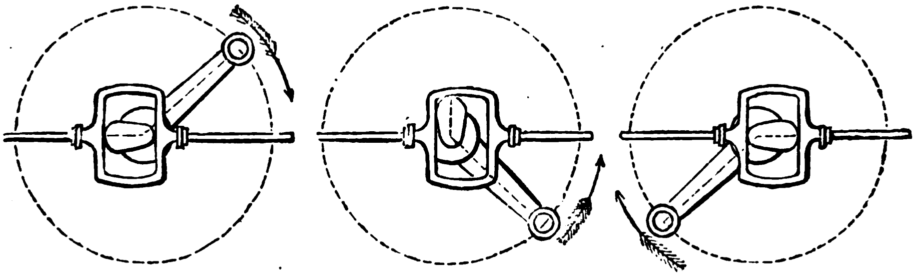
FIG. 4.



Side and End elevations of the Valves and Gear, as fitted to the Cornish Steam Beam-Engines in the year 1820.

A drawing of the original cam and frame is shown by Fig. 5. They are shown in three positions: first, cam at full stroke, to the left hand;

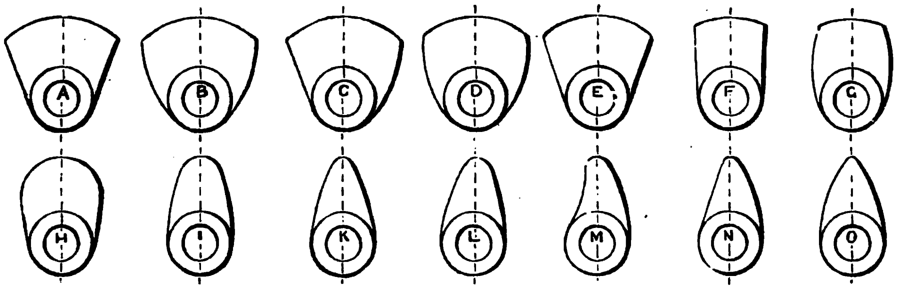
FIG. 5.



Elevations of the original Cam and frame Valve-gear, as introduced in the year 1820.

next, at half stroke; and third, at full stroke at the right hand. After the introduction of those, cams were made of almost every conceivable shape, as illustrated by Fig. 6.

Fig. 6.

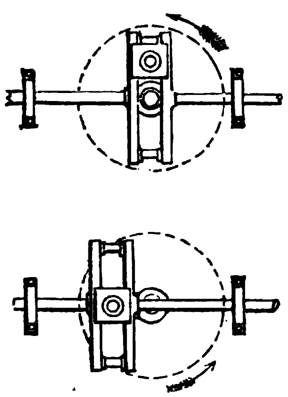


End elevations of a series of Cams for imparting motions to the Valves of Steam Engines as used from the year 1821 to the year 1870.

A. Broad Cam with straight sides.
B. „ „ with curved sides.
C. „ „ with straight and curved sides.
D. „ „ curved sides and round corners.
E. „ „ straight sides and round corners.
F. Narrow Cam with parallel straight sides.
G. „ „ with curved sides.
H. Narrow Cam, with semicircular driving edge.
I. „ „ with elliptical driving edge.
K. „ „ with elliptical driving edge.
L. „ „ with uneven sides.
M. „ „ with concave and convex sides.
N. „ „ with convex and straight sides.
O. „ „ pointed.

Next came the gear, as shown by Fig. 7, which imparted a reciprocal but constant motion to the rod, whereas the cam permits the rod to be *still* for a period, the time of which is proportionate to the form of the driving part of the cam. This gear is used in the present day for donkey-engine pumps.

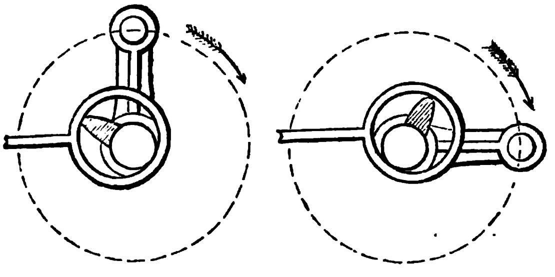
Fig. 7.



Crank-pin and Stop-valve Gear, introduced in the year 1820.

Following that, the eccentric band and cam were used, as depicted by Fig. 8, which is

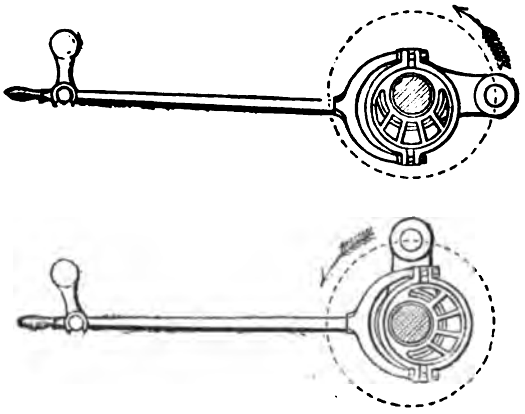
Fig. 8.



Narrow Cam and Ring Valve Gear, introduced in the year 1820.

merely a cam of the narrow order enclosed in a ring, and that arrangement was the beginning of the eccentric motion for valve-gear, as illustrated by Fig. 9.

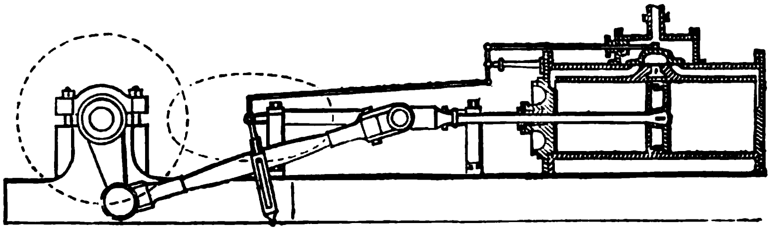
FIG. 9.



Eccentric-Motion for Valve-Gear, introduced in the year 1820.

This was really a great improvement over the cam-motion, because it was practically applicable for quick speed engines, for which the cam-motion is *not;* but even with that attainment the inventive mind was not content, for in the year 1830, Mr. Melling, the then locomotive superintendent of the Liverpool and Manchester railway, introduced a form of valve-gear as illustrated by Fig. 10; for locomotives were in full use then, and thus the valve-gear had had great consideration by

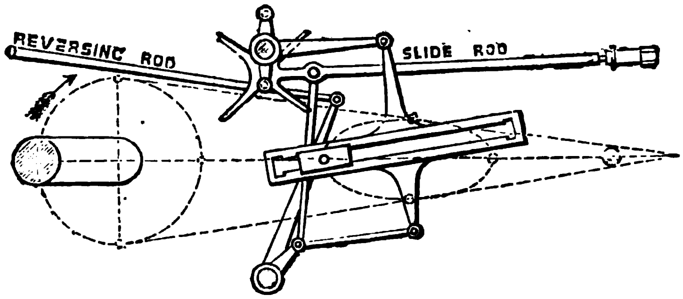
FIG. 10.



Melling's Slotted Lever and Connecting-rod motion for Valve-Gear, invented in the year 1830.

the leading railway engineers. Mr. Melling considered that he could supersede the eccentric by putting a stud midway of the length of the connecting-rod, and attach thereto a slotted end lever, by which connection a slip of the connecting rod's motion would reduce the travel of the other end of the lever sufficiently for what was required for working the slide valve as shown. It will be noticed also that the centre of the stud describes an ellipse, and we may explain, too, that the motion imparted to the valve by this arrangement is the slowest when it should be the quickest, such as for "supply steam" and "cut-off," hence it was never universally adopted. That fact, however, did not prevent Mr. Hawthorn, in the year 1838, from introducing his arrangement, as illustrated by Fig. 11, which is similar to Melling's, the connecting-rod having a stud in it, and the working lever being slotted where attached thereto.

FIG. 11.

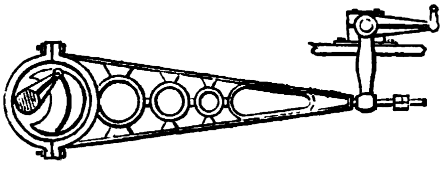


Hawthorn's Slotted Lever and Connecting-rod motion for Valve-Gear for Locomotive Engines, invented in the year 1838.

We here pause in our systematic historical travel, and direct the reader's attention to the fact that, when the locomotive engine was introduced in the year 1820, the "cam and frame" were previously adopted for the valve-gear; but as those were of no use for reversing, a *loose* eccentric and band were invented, as shown by

Fig. 12. A Mr. Wood did this, the engineer of the Killingworth engine factory.

FIG. 12.



Side elevation of the Killingworth Locomotive Engine Valve-Gear, being loose Eccentric and fixed Stops for reversing, used from 1820 to 1830.

Mr. D. K. Clark, in his excellent—and, indeed, the only reliable—work on the locomotive engine, decribes this gear thus : "A lever was fixed upon and revolved with the driving axle formed with a stud which entered and slid freely in a concentric groove cut in the body of the eccentric. The stud found its way to one end of the groove and determined the position of the eccentric on the shaft for the fore or back gear. The small end of the eccentric rod was permitted some longitudinal play in the eye of the intermediate lever—adjustable by nuts."

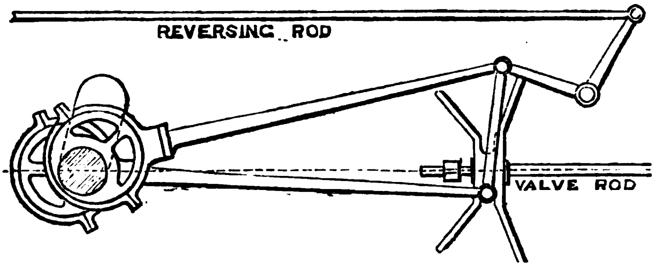
We here remark that this method of permitting the eccentric to *slip* for a certain length of arc on the shaft is precisely as that adopted in the present day by marine engineers for the "single eccentric" reversing gear for oscillating paddle-wheel engines.

After the adoption of the loose eccentric in 1820, Mr. Clark in his work informs his readers that gabs or levers were adopted on the end of the eccentric rods to impart proper motion to the levers in connection with the valve rods, and many arrangements were proposed for that purpose up to the year 1840, when Stephenson improved on the whole by introducing his arrangement as shown by Fig. 13, on the next page, and this motion being the most simple, was of course the most direct.

The use of steam expansively in the locomotive cylinder, a little before this date, had not had much practice. Watt, bear in mind, had accomplished it with his engines, but he worked their pistons at a slow reciprocating motion, and the cylinders were roomy, and, therefore, time and space were at his disposal for the expansion requirements. But the locomotive engineer had to contend with a quick motion for the piston and a small cylinder to accomplish the same result, if possible, as

Watt did. The slide valve applied had *no* lap, so to speak, for it only covered the outer edges of the supply ports, $\frac{1}{16}$th of an inch, when at half stroke. *Wide* bars were cast between the supply and exhaust ports, and the valve had no proportion relative to its duty, so the result was, that the admission of steam occurred for nearly the entire stroke of the piston, and its expansion was only momentarily, while the exhaustion *began* when the piston completed its stroke, and *finished* after the return travel was a good way entered on.

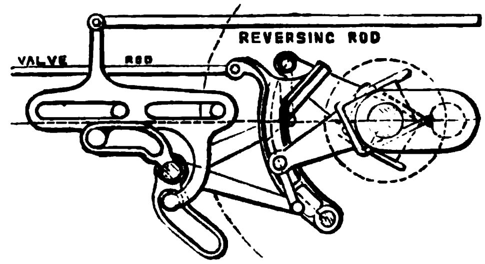
Fig. 13.



Stephenson's Gab and lever Valve-Gear for Locomotive Engines, for reversing with two Eccentrics, applied in the year 1840.

That way of regulating the steam was of course the *worst* possible, and if the engineers in question had tried their utmost to have exceeded the evil by any other means they could not have done it so successfully. Their knowledge, therefore, of the actual properties of steam must have been very vague, so much so indeed that they were using it without any discrimination. The only fact apparent to them must have been, that the steam when it got into the cylinder must be allowed to escape from it, and thus their aim was accomplished by the valve alluded to as used in the year 1838. At that date the engineers were put to their wits' ends how to reduce the consumption of the fuel, for that matter made a great hole in the profits of railway management; and the result was that the slide valves were after then, made with an outside lap of from $\frac{1}{4}$th to $\frac{3}{4}$th of an inch, varying by $\frac{1}{16}$th and $\frac{1}{8}$th, when in the year 1840 *one* inch lap was adopted. And thus nearly one-half the fuel was saved because one half the steam was used, and time and area permitted for its expansion and exhaustion. The locomotive engineer was not, however, content with outside lap for the valve only, for even before the last date quoted, or in 1839, Mr. John Gray applied his invention of expansion-gear, as shown by Fig. 14, to the "Cyclops" locomotive engine on the Liverpool and Manchester railway, which produced an economy of fuel amounting to 12 per cent. over the other engines then in use.

FIG. 14.

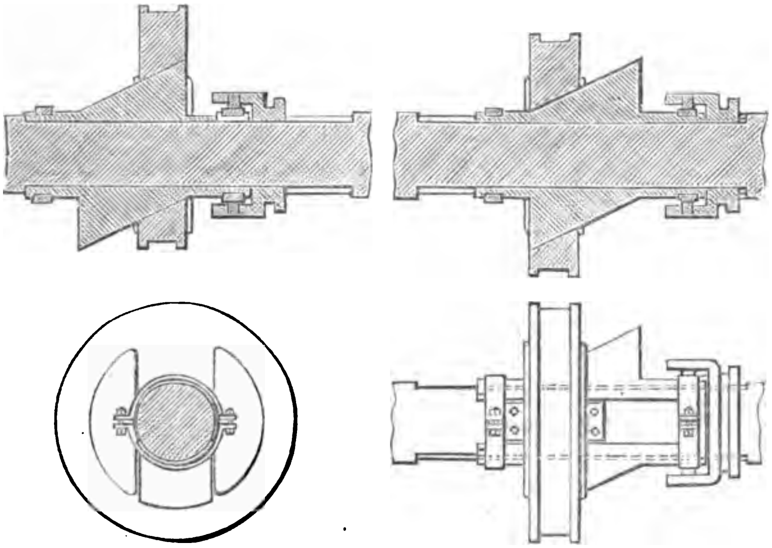


Gray's Slotted-Valve-Gear for Locomotive Engines, for altering the Grade of expansion, practically applied in the year 1839.

Mr. Clark in his work describes this gear as follows: "The pin of the eccentric rod works in a segmental lever curved to the radius of the rod, the upper end of which is linked to the valve spindle. Thus the lever, being concentric with the fore rod at the beginning of the stroke, the rod can be raised or lowered in the slope of the lever to any requred distance from the fulcrum, which of course regulates the travel of the valve while the lead remains unchanged. The reversing mechanism consists principally of a wrought iron frame which slides horizontally on two fixed pivots and carries rollers, which, working in grooved levers linked to the eccentric rods, places these rods in and out of gear with the segmental lever, as required. The action of reversing is in this mechanism very suddenly performed in the quick bends of the grooved levers. And accordingly in practice very great manual power was demanded for the operation."

At the same time as Mr. Grey applied his gear, Isaac Dodds and William Owen of York invented and patented an arrangement of expansion-gear that has been often termed "Dodd's Wedge Motion," which is shown by Fig. 15, in two sectional and two complete views. This arrangement consists of the eccentrics being mounted on their shaft between guide pieces or ears fixed thereon, so as to prevent the eccentrics sliding laterally on the shafts, but allowing them to move between these ears transversely. The parts which move the eccentrics

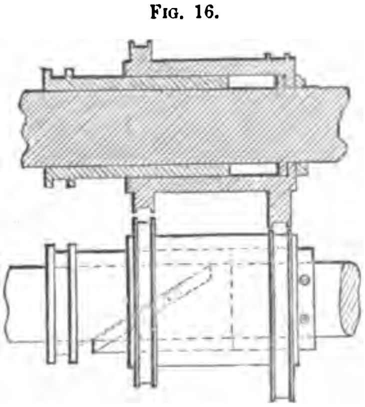
Fig. 15.



Dodd's "Wedge-Motion" for shifting the eccentrics, to alter the cut-off and reversing, invented in the year 1839.

more or less from the centre of the shaft, are inclined planes or wedge-shaped pieces sliding laterally upon the shaft, and passed through slots or openings in the eccentrics, so that as they are forced through them they shall change the relative positions of the centres of the eccentrics and shaft. These wedge-shaped pieces are securely connected to the shaft by keys working in long slots, to prevent the inclined planes slipping round upon the shaft, consequently they are made to revolve with it, and by passing through slots in the eccentrics also cause them to revolve with the shaft. The inclined planes or wedges are connected to a clutch box moved by a forked lever, used to slide them laterally to and fro upon the shaft without interrupting their rotatory motion. Dodd and Owen proposed also at the same period another method, as illustrated by Fig. 16, in two views, sectional and complete. This mechanism is also mounted on the rotatory shaft, and acts upon the eccentrics belonging to the valve motion so as to change their position. It consists of an inner tube or long collar embracing the shaft, and mounted so as to slide laterally along it and at the same time partly around it, like the motion of an inside screw around an outside screw. In this tube or collar is formed a curved slot or groove, and upon the rake or inclination of the curve of this slot depends the movement of the eccentric. On the shaft is fixed a pin or stud, which projects into this groove; and, therefore, whenever the collar or tube is moved longitudinally along the shaft, the pin will cause it, by its connection with the groove, to move around the shaft. The eccentrics are fixed upon another, or outer, tube or barrel embracing the shaft and inner tube, or they may form the tube itself, but is prevented moving longitudinally by means of a fixed collar on the shaft and coupling piece. This outer tube or barrel is securely connected to the inner one by means of a key or feather and a slot, capable of sliding one along the other, so that whenever the inner tube is moved laterally along the shaft it will be drawn out of the interior of the outer barrel; and in consequence of the pin on the shaft being in connection with the curved groove, the inner tube will be made to move around the shaft; and this inner tube, by means of its connection—the key and slot—will cause the outer barrel to move with it in the same direction, with increased or decreased rotatory speed to that of the shaft, and, consequently, the eccentrics will be made to move into another or opposite position and change their places upon the shaft. If thought desirable the curved slot or groove may be formed upon the shaft and the pin

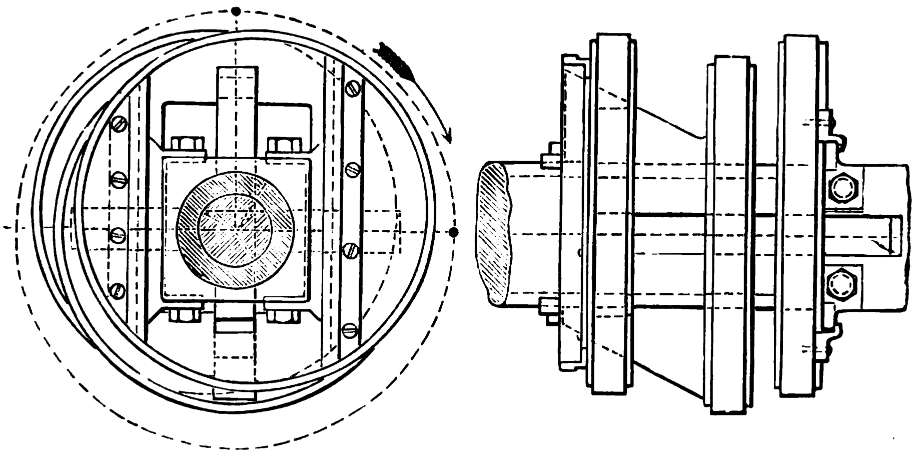
FIG. 16.



Dodd's Slot and Wedge-Motion for Shifting the eccentrics, and alter the cut-off and reversing, invented in the year 1839.

fixed in the inner tube, and by this arrangement of the parts the same effect will be produced. Both of those methods were soon after more practically arranged, as shown by Fig. 17, by Mr. Dubs, of Glasgow.

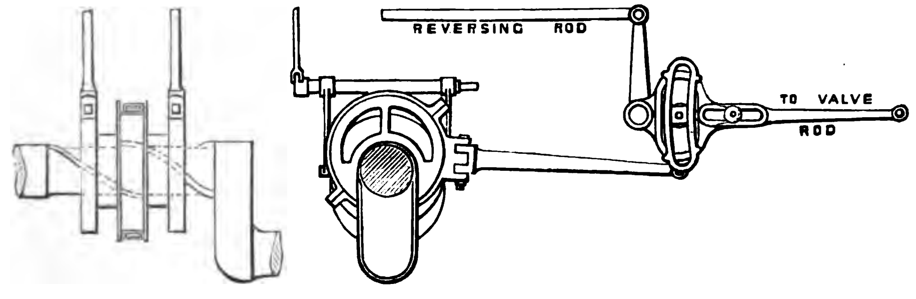
Fig. 17.



Dodd's Wedge-Motion as arranged by Dubs, in the year 1842.

The next approach to Dodd's gear is Fenton's, and that is shown in two views by Fig. 18, which is a combination of sliding eccentrics and link motion. The eccentrics are fixed on the shaft by a spiral feather, which adjust them also to any angle for the grade of cut-off and lead. The

Fig. 18.

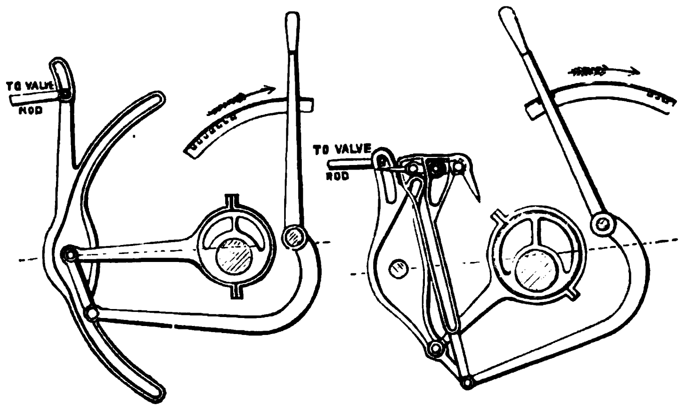


Fenton's Sliding-Eccentric Valve-Gear for Locomotive Engines, introduced in the year 1842.

link is hung on a fixed centre and the connecting rod of the valve rod is slotted as shown.

In the year 1842, Mr. Crampton, the then well-known locomotive engineer, invented, and patented his arrangement of link motion, as illustrated by Fig. 19. The left-hand arrangement shows the eccentric out of gear, during which, while in motion, the end of the eccentric rod works backwards and forwards in the widest or enlarged part of the groove on the lever, without causing the same to vibrate; but when the handle is shifted in the direction of the arrow to the first notch in the quadrant, the end of the eccentric rod is forced upwards into the narrow part of the groove until the rod forms an angle of about twenty-one degrees with the centre line. The motion of the eccentric will now give a reciprocating action to the lever and the valve rod. When the eccentric rod works at an angle of twenty-one degrees, as described, the slide valve is arranged so as—with a lap of about one inch—to cut-off the steam at about seven-eighths of the stroke of the piston. By forcing the handle still further in the direction of the arrow to the last notch on the quadrant, the end of the eccentric rod will be raised to the top of the grooved lever, and will then form an angle of about fifty-nine

Fig. 19.

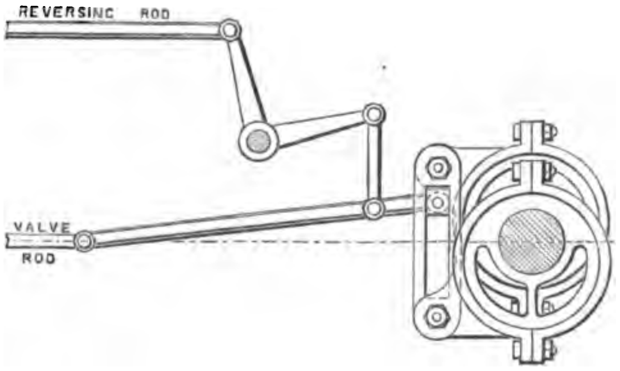


Crampton's Link Motion for Locomotive Engines for reversing, patented in the year 1842.

degrees with the centre line. The valve will then cut off the steam at about one-third of the stroke of the piston. By fixing the handle at any of the intermediate notches, the cut-off of the steam will range between about seven-eighths and about one-third of the stroke of the piston. By moving the handle back in the opposite direction to the arrow to the first notch on the other end of the quadrant, the end of the eccentric rod will be forced into the lower end of the lever, and the action of the slide-valve reversed, the steam being cut-off at about seven-eighths of the stroke, as in the forward motion of the engine. The eccentric rod, when inclined at the angles mentioned, will only permit the steam to be cut off in the proportions mentioned when the end of the valve rod is at the lower end of the slot. When the end of the valve rod is raised, the angles formed by the eccentric rod must be increased a few degrees. The formation of the curve of the groove in the lever is struck from the centre of the eccentric at the time the piston is at either end of the stroke. The eccentric must be fixed on the axle with the full part at a right angle to the centre line drawn through the centre of the eccentric and the axis of the lever, when the piston is at one end of the stroke. The arrangement on the right hand shows that the end of the eccentric rod is at the bottom of the groove of the lever, and the end of the valve rod is at the top of the slot, level with the top of the fork or gib ends: the slide valve being arranged to cut off at about three-fourths of the stroke, and give about five-eighths of an inch lead of admission. The lead for admission may be diminished by shifting the handle of the lifting lever a small distance in the direction of the arrow, which will raise the end of the eccentric rod and the link, and lift the fork from the stud on the short end of the small lever, and allow the tail end of the small lever to fall by the weight of the end of the valve rod, in consequence of which the travel of the slot and valve will be diminished. The valve rod is made to lift more than the eccentric rod, in such proportion as not to alter the cut-off of the steam by the inclination of the eccentric rod. The eccentric is thrown out of gear by raising the end of the eccentric rod to the middle or enlarged part of the groove on the lever, by forcing the handle to the notch on the middle of the quadrant. The engine is reversed by forcing the handle to the opposite end of the quadrant, which raises the end of the eccentric rod to the top of the groove in the lever, and at the same time raises the link, and the tail end of the small lever, in consequence of the stud being lifted by the bottom of the slot.

It is obvious that the principles of Gray's and Crampton's gear are pretty much the same, and that, although the inventors accomplished the same result, the mechanical contrivances were different, but both very complicated. Dodd's and Fenton's gear were less intricate, but not at all simple or certain; they, of course, used less detail than the other two, but at the cost of imperfect action which was nearly obviated by the link. Gray had first hit on an approximation of the requirements, and Crampton followed him, and he was tracked by Williams of Newcastle, who brought out the arrangement shown by Fig. 20.

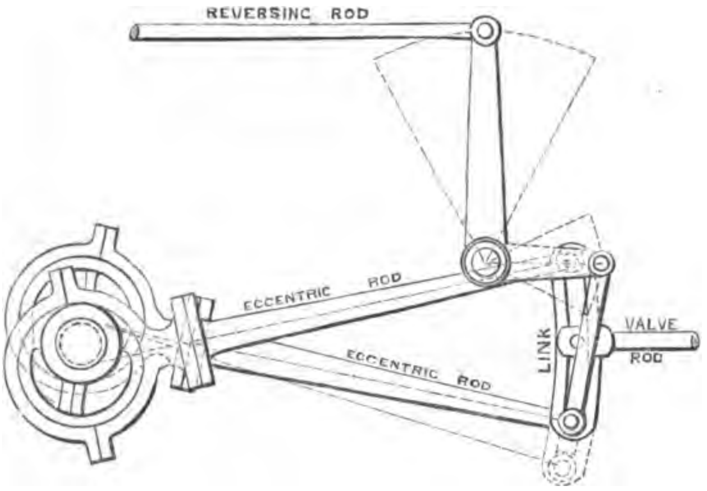
FIG. 20.



Williams' Link-Eccentric Valve-Gear for reversing engines, proposed in the year 1842.

That was an outburst of genius, and nothing short of a really inventive mind could ever have conceived it. And as Mr. Clark, in his work states, "It was rude and even impracticable;" but yet the idea for simplicity was good, and so far so that it doubtless paved the way for the introduction of the now well-known "*Link-motion*," which was first invented by Mr. Howe of Newcastle in the year 1842, and in the year 1843 it was practically applied by Messrs. Robert Stephenson and Co., as illustrated by Fig. 21.

Fig. 21.



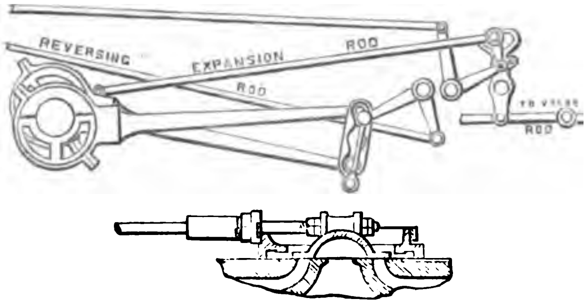
Howe-Stephenson's Link Motion for Locomotive Engines, applied in the year 1843.

It is really worth remarking here that all the prior inventors to that date must have worried themselves tremendously to have carried out their complicated arrangements; for their aim being vague was far short of the requirements for perfection of result, as much as their mechanical contrivances involved almost every conceivable complication possible; so that the little they understood about the regulation of steam in the engine cylinder was developed in the most adverse way for success. Indeed they must have forgotten that "wear and tear," as the phrase goes to express friction and the reduction of the strength of material, should always be considered primarily in relation to the efficiency of any mechanism, and in no case more so than the valve-gear of the steam-engine.

But to return again to our historical duties: in the year 1843, Mr.

Hawthorn, of Newcastle, improved on the arrangement he invented in 1838, as shown by Fig. 11 on page 13, and patented the valve-gear as illustrated by Fig. 22. The peculiarities of this arrangement are that

FIG. 22.



Hawthorn's combined Link-Motion and Expansion Gear for Locomotive Engines for two Slide Valves, patented in the year 1843.

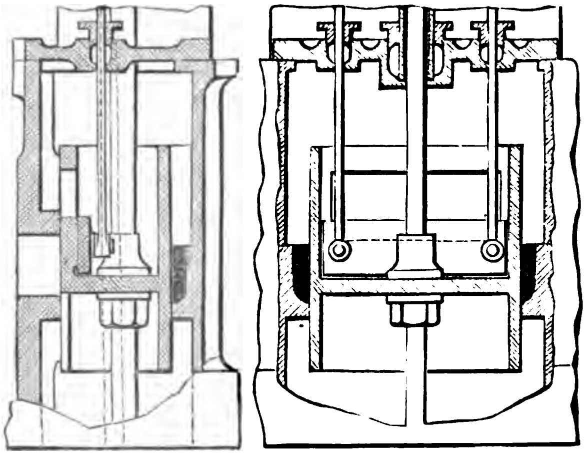
whereas steam had been heretofore used expansively in locomotive as well as other steam-engines, but in the case of the former with comparatively small advantage; for though by varying the stroke of the slide valve the steam is cut off at various portions of the stroke of the piston, yet at the same time the passages for the ingress and egress of the steam are constantly being changed, so that little or no benefit results from that mode of expansion. And whereas also there was great difficulty experienced in keeping the slide valve steam-tight, or in what may be called a perfect working condition, in consequence of the constant variation in the stroke, which tends to wear the surface or face on which it works irregularly. This was thought to be obviated by adapting to locomotive engines an auxiliary expansion slide frame, which fits with and works upon the same surface or face, and is actuated by the same eccentrics as the ordinary slide valve, whereby the said defects arising from the variation in stroke are fully remedied. This slide valve is kept constantly steam-tight, and rendered regular and uniform in its action, and the steam may be applied with full and unimpaired force until cut off, and may be cut off almost instantaneously at any portion of the stroke of the piston.

The ordinary slide valve is placed in a horizontal position, and worked directly from the driving axle by two ordinary eccentrics. The coupling link is of a peculiar form, which is contrived to diminish as much as possible the friction and wear upon the slotted ends of the eccentric rods and the connecting pin; the wide space in the middle part of the link allows the eccentric rods to work without moving the slide valve, so that the valve is constantly at rest, and closely shuts the ports when out of gear. The auxiliary expansion slide frame is fitted to and works upon the same surface or face as the main slide valve. There are projections on the inside of the expansion slide frame, so that when the frame is in motion it overlaps alternately the ends of the slide valve in a greater or less degree, according to the amount of the expansion. The valve rod is attached to the expansion slide frame in the usual manner, and made hollow, in order that the rod of the ordinary slide valve may pass through it, or it may be made also solid, similar to that of the slide valve, and worked through a separate stuffing box either above or at one side of the slide rod. The fixed pivot or short weigh bar supports the two levers that are worked or fixed upon the said pivot or short weigh bar, as the case may be; the lower end of one of the levers is connected by the links and the rod to the expansion slide frame, and the upper end of the other lever is connected by the rod to the back eccentric, or for working the engine backwards, so that by the gearing thus described the said eccentric communicates its motion to the expansion slide frame. There is a groove or slot in which the pin at the end of the rod moves; and also gearing by which the engine driver can vary the position of this pin at pleasure, and thereby cause the stroke of the expansion slide frame to correspond exactly with the amount of expansion required. A dial is placed at the foot plate in view of the engine driver, which indicates minutely the amount of the expansion at any part of the stroke. When expansion is not required, the pin is raised into the loop, and at the same time the inclined surfaces on the end of the lever press against the pins which keep the expansion slide frame firmly secured and at rest when out of gear, and thereby prevent all unnecessary wear and tear.

This arrangement was the first of its kind to cut off the steam by a separate valve with the use of the main valve.

In the year 1844, Mr. James Petrie, of Lancaster, came forward in the ranks of inventors, with his idea of what a separate cut-off gear should be, which was an arrangement of a cutting-off "plate-valve" placed in the inside of the main valve, and both being worked by a cam and an eccentric. The form of the valves and casing for each end of the cylinder is shown by Fig. 23, in side and front sectional elevations: the mechanical peculiarity is thus:—The partitions which separate the steam supply end from the exhaust end are placed near to the exhaust side of the bars, which traverse across the ports in the facing on the nozzles of the cylinder, so as to make sufficient room for the sliding or "cutting off" plates; there is also another bar across the face of the valve at the extremity of the steam end; the space between the bars forming a port.

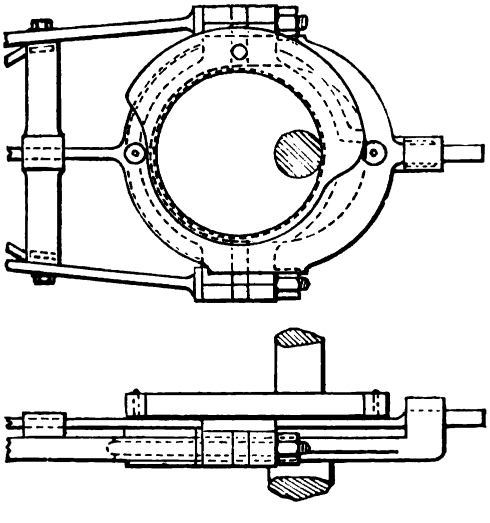
Fig. 23.



Petrie's combined Main and Plate, cut-off Valves for using the Steam expansively in the Cylinders of Land Engines, patented in the year 1844.

These two bars are finished to a plane surface on both sides, viz., on the side which slides on the facing on the cylinder nozzle, and also on the side enclosed by the semicircular part of the main valve ; on the last-mentioned surface is the sliding plate or "cutting-off" valve for cutting off the steam, and both valves are connected together by means of rods passing through stuffing boxes in the bottom of the top steam box, and in the top of the bottom box; these two sliding plates are connected with gear hereafter described in such a manner as to cause them to partake of the motion of or move along with the main valves for any portion of the stroke, and also to move on the inside facing of the main valves, so as to close either of the openings, and thereby cut off the steam for the remainder of the stroke. When the sliding plate covers the port in the face of the lower main valve, the top sliding plate is in such a position to leave the port in that valve uncovered and *vice versâ*. The cam and eccentric gear is shown in side elevation and plan by Fig. 24. The eccentric is made broader on the periphery or edge than usual, and has a groove turned in it, as in common, for the reception of the clips connected to the common eccentric rod. This groove is close to one edge; and on the remaining portion of the breadth is fitted a moveable cam. The edge of this cam is concentric with the eccentric, except at the two inclined portions. These inclined portions act on friction rollers that are connected to an elliptical ring, to which is attached a rod which leads to the "cut-off" valves. This elliptical ring is steadied by guides so as to move only in a direct line with

FIG. 24.



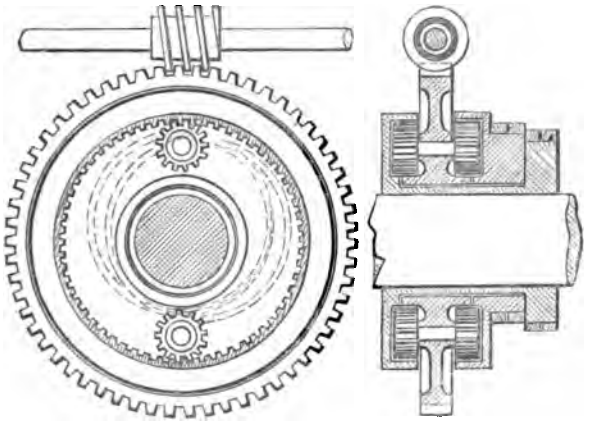
Petrie's combined Cam and Eccentric Valve Gear, for two Slide-Valves for Land Engines, patented in the year 1844.

the respective rod to which it is attached. The point at which the steam is cut off is varied by shifting the movable cam, on the common eccentric, either forwards or backwards as required. As the cam revolves along with the eccentric, and as the acting surface of the cam is, as stated before, concentric with the eccentric, except at the projections, this motion will alternately draw the cam rod backwards and push it forwards. Mr. Petrie, also, at the same time, proposed an arrangement of gearing in connection with the engine-governor, which was a very complicated combination of bevel and mitre wheels, worm and wheel, cams, and sun and planet motions, with levers and weigh shafts, eccentric rods, and the necessary details attending the whole.

After Mr. Petrie, Mr. Leigh of the same county, came, in the year 1849, with his appeal for a patent, which was granted for his invention of valve-gearing as particularly applicable to oscillating engines for marine purposes, which class of engine had just then came into consideration: we may mention also that Mr. Leigh trod pretty hard on Mr. Petrie's toes in this matter as far as the worm and wheel, and sun and planet motions were concerned; although Mr. Petrie shows his application as for stationary engines.

Mr. Leigh's valve-gear is shown in side and end elevations by Fig. 25, and the arrangement of the detail is as follows:—Upon the crank shaft is keyed or otherwise firmly attached an eccentric for the purpose of effecting the ordinary motion of the slide valves, surrounding which eccentric is formed a ring having a spur wheel with internal teeth formed therein. Mounted loosely upon the boss of that eccentric is another eccentric from which a rod passes, that is connected with the expansion valve: this latter eccentric is provided with a similar spur wheel as the fixed one. A worm wheel is also mounted loosely upon the boss of the eccentric and carries within it, by means of a short shaft turning freely therein, four small pinions, one pair of which pinions gear with the teeth of the toothed wheel upon the fast eccentric, and the other into the similar wheel attached to the loose eccentric, so that as the fast eccentric revolves with the crank shaft, it will by means of its toothed wheel and pinions turn round the other pinions, which will communicate motion through the spur wheel to the loose eccentric, at an uniform speed and in the same direction with that of the fast eccentric, providing that the worm wheel shall remain stationary; in which case the eccentrics will actuate the slide valves and expansion valve uniformly at every stroke of the engine. But if the said worm wheel shall be caused partially to revolve, then, by means of the pinion, the loose eccentric will be caused to move around the crank shaft, and its position relatively with that of the fast eccentric will be altered; and in order to effect this, a worm wheel is connected with the governor of the engine by means of a worm mounted on a shaft, the other extremity of the said shaft being provided with a roller running upon a friction disc.

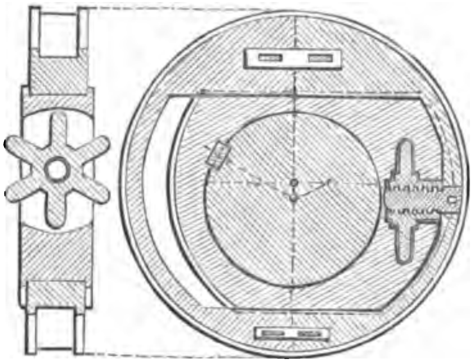
FIG. 25.



Leigh's combined Tooth-wheel and Eccentric-Gear, for two Slide Valves for Oscillating Marine Engines, patented in the year 1849.

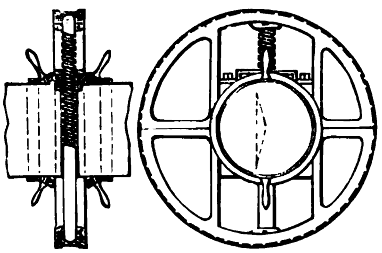
In the year 1850, Mr. Charles Atherton, of Devonport, patented a series of mechanical arrangements for adjusting the "throw" of the eccentric by a regulating screw and nuts, and also by gearing, and other nearly similar contrivances diversely situated: the pith of his entire proposals is embodied in the arrangement illustrated by Fig. 26 in two sectional views; which is that the body part of the eccentric is so formed as to enclose or contain a block which surrounds the crank shaft and is fixed at an angle thereon. The eccentric proper has fixed in its body a regulating screw, that passes through a hand-nut, and on turning the hand-nut, the eccentric can be shifted in either direction as required. We have added the eccentric in halves and the connecting pins and keys to Mr. Atherton's imperfect drawing accompanying his specification so as to make it practically understood here; it may be noticed, also, that the hand-nut may be turned around while the eccentric is in motion by means of a ratchet, which can be shifted by a handle, and screwed rod attached thereto for that purpose.

FIG. 26.



Atherton's Adjustable Eccentric for attaining a range of cut-offs with one Valve, patented in the year 1850.

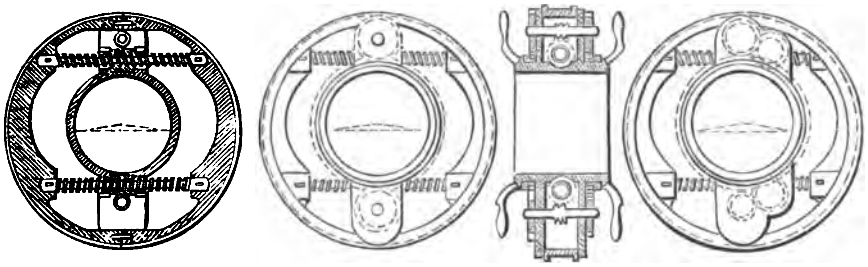
FIG. 27.



Atherton's Adjustable Eccentric for attaining a range of cut-offs with one Valve, patented in the year 1850.

Mr. Atherton proposed nine different methods of valve-gearing in all, eight of which were far more complicated than that illustrated here by Fig. 26, they being a complication of—screws passing end to end against the shaft, screws one each side of the shaft, screws passing through the shaft, and screws actuated by nuts or pinions, which not only altered the throw of the eccentric but its angle also. Fig. 27, is of the latter order, and shows an arrangement for altering the adjustment of the eccentric wheel without stopping the action of the engine or of the expansion valve. In this case the regulating screw is fixed at each end to the rim of the eccentric wheel, and passes through the shaft, but in such position that the axis or centre line of the screw is not only parallel to the centre line but also passes through the axis of the shaft, and a nut, of which the circumference forms a bevelled pinion wheel, is attached to the shaft like a swivel, which on being turned round operates upon the screw. The four illustrations, Fig. 28, represent three other arrangements of eccentric apparatus in which the regulating screw does not pass through the shaft, as in Fig. 27 : but two regulating screws are made to pass one at each side of the shaft, and each of these screws is fitted with a nut, the circumference of which is formed to form an endless screw wheel or rack work, which is operated upon and turned round by the tangent screws. And as these nuts are confined between the snugs or ears which project from the shaft or from the ring that is fitted to the shaft, while the snugs are so situated on the shaft that the centre line or axis of the leading screws shall be parallel to the centre line of the eccentric; it follows, then, that the regulating screws will be so fitted that the centre of the eccentric wheel may be made to move in either direction on that centre line according to the direction in which the tangent screws are turned.

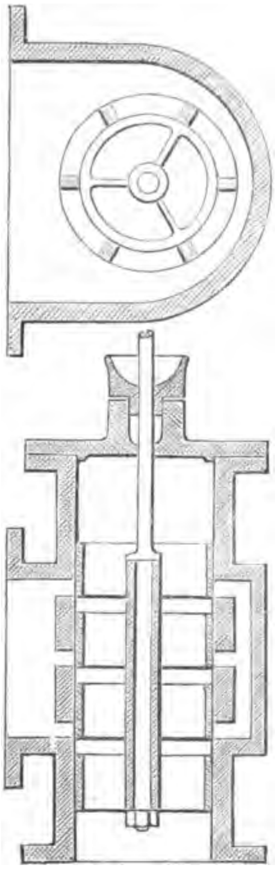
FIG. 28.



Atherton's Adjustable Eccentrics for attaining a range of cut-offs with one Valve, patented in the year 1850.

Now, in order that the tangent screws may be turned in either direction, each end of the spindle of each tangent screw is fitted with a pinion wheel, and one side of the eccentric wheel is fitted with a spur wheel, as shown in the second view, running loose upon the saddle concentric with the centre of the shaft, and in gear with the pinion. But when the other side of the eccentric, as shown by the third view, is fitted with a spur wheel running loose on the saddle, but communicating with the pinion by means of the intermediate wheel by which the pinion and wheel are always in gear—all of which parts are also shown by the section—then by such an arrangement the tangent screws can be turned in either direction, according as the wheels on the one side or on the other may be held; or the toothed wheels, may be grooved pulleys, connected by bands so arranged as to produce the same result; and for the purpose of stopping the wheels or pulleys, stop handles, as in Fig. 27, page 30, may be attached to the wheels or stop levers, so as to obstruct their motion; or the stop levers may if required be so constructed as to be connected with the engine governor in such manner that the self-acting operation of the governor upon the expansive gear may regulate the speed of the engine.

FIG. 29.



Atherton's Cylindrical Equilibrum Expansion Valve, patented in the year 1850.

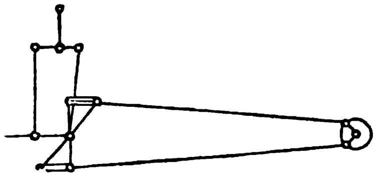
The most efficient portion of Mr. Atherton's patented ideas is his expansion valve which is perfectly equilibrium, and since the year 1850 has been largely used by land and marine engineers. Fig. 29 is a sectional elevation and plan of the valve and casing which is cylindrical. The valve is merely a tube with apertures through its periphery and open at each end with a central boss throughout its length, into which the motion rod is secured. The valve casing forms a belted pipe, which is bored so that the turned cylindrical surface of the expansion valve may fit therein, and through the belted part of which, annular apertures are likewise formed, of such dimensions and distances apart as to correspond with the apertures in the expansion valve representing the faces between the apertures. The steam has constant and free access to the interior of the expansion slide; and it is obvious that if the valve apertures are opposite to the casing apertures the steam will pass and get access to the main valve; but if the faces of the expansion valve are opposite the casing apertures, then the valve faces will also cover those apertures, and the steam will not pass, but be what is termed cut-off.

In constructing this expansion valve with a view to its being worked by the eccentric motion just before described, and produce the effect of cutting off the steam at any required period of the stroke for which the said eccentric may have been adapted, it is requisite that the length of the respective faces, or spaces between the apertures, be not less than the radius of the largest circle which the centre of the eccentric wheel or centre of the crank pin of the crank motion can be made to describe.

Nothing particular was done in valve-gearing worthy of record from 1850 until 1855, when Mr. Alexander Allan of Perth invented and patented his now well-known "Straight Link-Motion." It may be well to state that link-motions at that period were divided into two classes, termed the "stationary link" and the "shifting link." The stationary link motion was also divided into two kinds, namely, those in which the block was connected to the valve connecting rod through which its motion is conveyed to the valve, and those in which the eccentric rods were connected to the block. In the former case the link was curved to the radius of the length of the valve connecting rod, and the concave side of the link was placed towards the valve, and in the latter case the link was curved to the radius of the length of the eccentric rods, and the concave side of the link was placed towards the eccentrics. With the shifting link-motion the eccentric rods are usually connected to the link which is worked on the block, the link being curved to the radius of the length of the eccentric rods, with the concave side placed towards the eccentrics.

Mr. Allan's link-motion was a new combination of this mechanism, the novelty of which is, that the peculiar features of both the shifting and stationary link arrangements were combined, as both the link and block—or parts corresponding thereto—are moved to get the block pin or centre at the required position in or on its link or centre. As a consequent of such an arrangement, a link may be made with a varying or unlimited radius or combination of radii, or the centres of the double lever; parallel motion may be employed by attaching radius rods to a central bar, which carries the valve radius rod centre, as shown by the diagram Fig. 30. The other ends of the radius rods are connected to the eccentric rods, which are kept at the required distance apart by a strap or plate or straps and plates. He however preferred to employ a straight link, as shown by Fig. 31, in plan and elevations, which may be a box, open, or a bar link, according to convenience, as it will be found that the curves or arcs described by the movement of the eccentric and valve connecting rods will neutralize or compensate each other, and thus effect the object of the usual curve of the link in common motions. The movements of the link and block, or parts common thereto, were accomplished simultaneously, by jointing the rod, corresponding to that by which the link is sustained or suspended in the stationary link-motion, to an arm from a shaft or shafts, similarly as the reversing shaft, and connecting the valve-connecting or radius rod by a rod with another arm from the opposite side of the same reversing shaft; by which arrangement it will be seen that the movement of the reversing shaft will give to the link and valve rod and block—or parts common thereto — movements in opposite directions, of such extent as will be regulated by proportioning the lengths of the arms from the axis or centre of the reversing shaft or shafts. From the combination of valve-gear just described, the following advantages were said to occur over the common link-motions, namely:—The mechanism is more simple

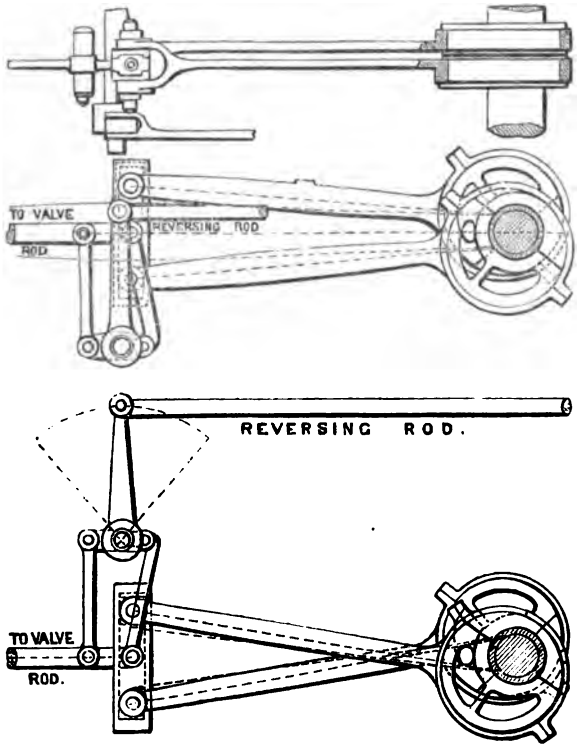
Fig. 30.



Allau's diagram of his Straight-Link-Motion. Patented in the year 1855.

in construction, and more easily maintained in repair than common link-motions; it requires less room than the shifting link; the angular position of the eccentric rods as compared with the one class, and the valve-connecting rod as compared with the other class of common link-motions, is much reduced; consequently the eccentric and valve rods move through less space and are more direct acting; the eccentric rods, link and valve-connecting rod and block, or parts belonging to them, balance each other, or nearly so, and thus dispense with a counterbalance weight; and, lastly, less power is required to move to or fix the valve gear in the required positions than in the common link-motions.

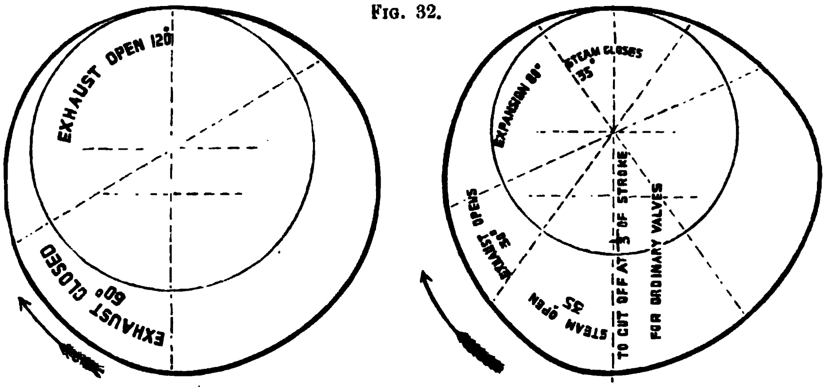
Fig. 31.



Allan's Straight-Link-Motion, patented in the year 1855.

In the same year, 1855, Mr. Kenworthy, of Lancaster, introduced a differential eccentric for working the slide valves of steam engines. He shaped the curves or form of the driving edges of the eccentric on mathematical principles, as shown by Fig. 32. Mr. Kenworthy arranges his method for shaping the curves as follows: Suppose it is required to construct a differential eccentric to cut off steam at five-twelfths of the stroke of the piston with a common slide valve. First fix upon the size of the boss to suit the diameter of the crank shaft, then set the crank pin so that its radius will give the eccentricity required to traverse the valves. Now, five-twelfths of the stroke corresponds nearly to an angle of eighty degrees, that is to say, the steam must be shut off when the crank pin is at an angle of eighty degrees. And suppose we begin to open and close the exhaust port when the piston is at one-sixteenth of the stroke from its terminus, or at an angle of thirty degrees nearly from the return of the engine crank: we have then to close the steam opening in forty degrees to expand by lap in seventy, to open for exhaust equal to lap in thirty, and to open for steam at the opposite end in forty, making a total of one hundred and eighty degrees, or one half a revolution. And supposing the thoroughfare to be three inches and the lap two-thirds of the thoroughfare, equal to two inches, the steam opening one inch and a half, we shall require a traverse of seven inches;

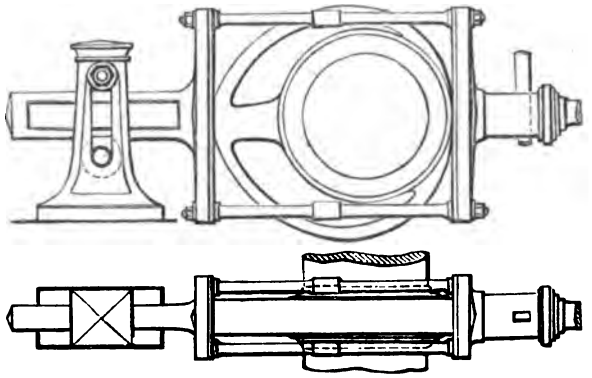
FIG. 32.



Kenworthy's Differential Eccentric, patented in the year 1855.

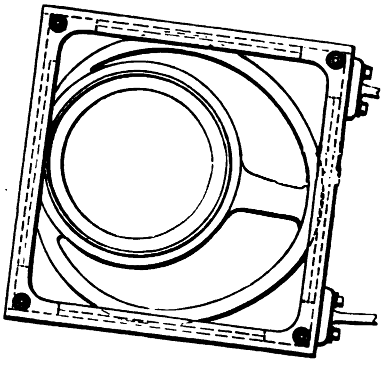
then say, close steam opening one inch and a half, equal to forty degrees, expand by lap two inches, equal to seventy degrees, exhaust opens two inches, equal to thirty degrees, open for steam one inch and a half, equal to forty degrees, total seven inches and one hundred and eighty degrees. The construction or setting out will be thus:—First make the radius or small crank on the drawing paper equal to three inches and a half, so that half a revolution will give a traverse of seven inches; then set off on a disc upon which the eccentric is to be delineated or drawn the respective angles, or from the ring of the disc, which shows the number of degrees, and then join those points by the curves as illustrated. The Fig. 33 is a side elevation and plan of the eccentric and frame as arranged for direct action; and Fig. 34 is an elevation of another of a different form.

Fig. 33.



Kenworthy's Differential Eccentric and Frame for Valve-Gear, patented in the year 1855.

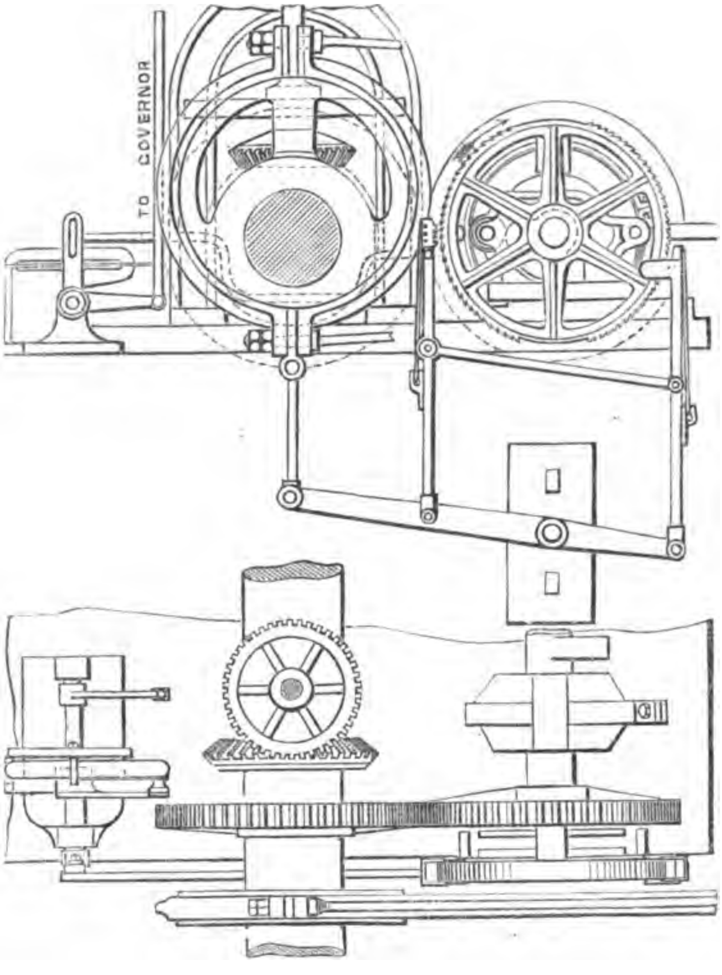
Fig. 34.



Kenworthy's Differential Eccentric and Frame for Valve-Gear, patented in the year 1855.

It will be remembered that on page 28 we noticed that Mr. Petrie, in the year 1844, proposed a complicated arrangement of valve-gear, and we now illustrate an improvement on that gear, which was patented in 1856, by Fig. 35, which is a differential motion for the working the slide valves. The gear is partially enclosed in a shrouded casing.

FIG. 35.

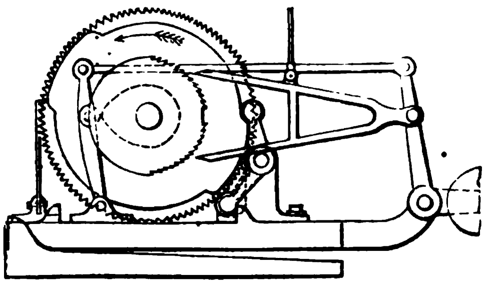


Petrie's arrangement of Cam and Catch, Expansion Valve-Gear, patented in the year 1856.

The wheel by means of a friction clip being the retaining medium, the wheel must therefore be fast upon the driving shaft. The wheel, which revolves on the shaft, receives motion from the crank shaft by means of the spur wheel keyed thereon, and gears into the wheel fixed upon the boss of the wheel. Upon one end of the shaft the ratchet wheel is also keyed, and which is actuated at suitable periods by the swinging catch levers, which are attached by suitable joints and pins to the vibrating lever mounted upon the stud, secured in a suitable manner to the framework of the engine. The lever receives motion in this instance from the eccentric by means of the connecting rod or link attached thereto, so that a vibratory motion will be imparted to the actuating clicks attached to the catch levers or arms. To the lever or arm is also connected a rod, the other end of which is by a suitable joint connected to the bell-crank lever, keyed on the shaft or stud mounted on the bracket. The other arm of the bell-crank lever has a rod or bar connected at its upper end to the lever, which partakes of the variations of the governor. Suppose that the speed of the engine is required to be reduced, the governor would, by means of the lever, rod and bell crank, actuate the swinging lever and click, so as to cause it to operate against the ratchet wheel, thereby causing the said ratchet wheel to turn in the direction as indicated by the arrow, at the same time by means of the retaining wheel and variable wheel altering the relative position of the cam, which effects the "cutting off" with the valves. Should the speed of the engine require to be increased, then the action of the swinging catches would turn the ratchet wheel, and consequently the cam, in a reverse or contrary direction, thus regulating the expansion and speed of the engine. To prevent any undue fluctuation of the governor, there is a spring or other suitable elastic medium attached to the brackets or frame at one end; the other end thereof acts against a lever fixed upon the spindle or bar. The force of the spring may be increased or diminished by moving the part in the slot. The motion of the cam may be imparted to the valves or slides by any other suitable arrangement of apparatus; that, however, preferred, is shown with a friction roller or bowl, against which the cam acts, and is mounted in a frame which slides in suitably formed grooves or slots, and to which the rod or bar is attached that connects it with the slide valve that regulates the steam in the engine cylinder.

Fig. 36 is a skeleton view of the details that especially relate to the stopping or "catch" portion of the gear. The differential motion is shown, as before described, enclosed. The driving bevel wheel, the intermediate or retaining wheel, upon which is mounted the usual bevel wheels which communicate motion to the variable wheel, are shown in plan on page 38. Upon the shrouding of the wheel there are cams formed, the boss of which has also the heart wheel fast therein, and also the cam, which communicates motion to the valves or slides for cutting off the steam, in the manner before mentioned. The wheel and cams run loose on the shaft to which the ratchet wheel is attached. The double swinging catch lever, mounted on the lever or arm, turning on the centre in a bracket or other suitable part formed on the framework, is shown in position out of gear. The rod or bar connecting the swinging catch to the governor is vertical. Instead of the intermediate or retaining wheel being locked, as before described, by means of a friction clip, it is in this instance toothed on its periphery, and is locked or unlocked by means of the cams acting against the double lever, so as to bring the locking catch in contact therewith, or withdraw it therefrom. The heart wheel is in such an angular position with respect to the cams that it will actuate the lever at the time when the wheel is unlocked, when the double swinging catch will, by means of the rod, be brought into a suitable position for effecting the desired change of the cutting-off cam, as aforesaid.

Fig. 36.



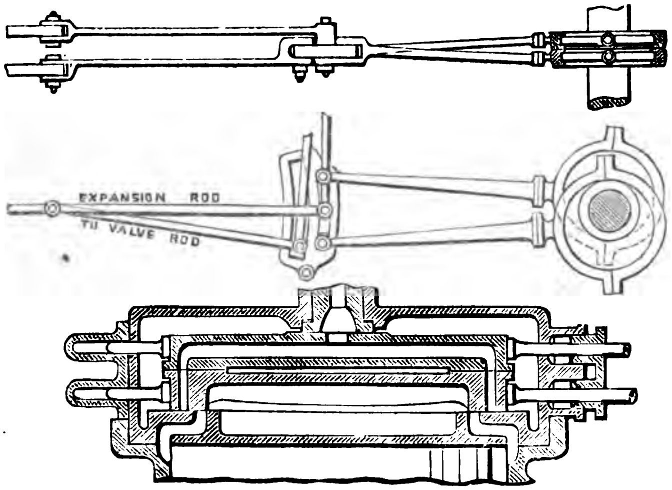
Petrie's arrangement of the Cam, Catches, Levers, and Rods of his Expansion-Gear, patented in the year 1856.

In order to prevent any unsteadiness in the intermediate wheel when it is unlocked, there is a spring having teeth on it corresponding to those on the periphery of the wheel, which will thus partly hook or hold it; or an arrangement of friction apparatus may be employed for this purpose if most applicable.

From the foregoing description it will be evident that as the governor actuates the double swinging lever, the heart wheel and ratchet wheel will effect the desired object of changing the relative position of the cutting-off cam, and consequently alter the position of the slides or valves with respect to the steam ports or passages. The differential wheels are actuated by the wheel which gears into that on the crank shaft, as before explained.

In the same year, 1856, Messrs. Charlton and Turnbull, of Essex and Surrey, patented a peculiar arrangement of link-motion and double valves in connection therewith. The illustrations shown by Fig. 37 are a side elevation and plan of the link-motion, and a section of the slide valves and casing, with a portion of the cylinder. The eccentrics are keyed on the crank shaft in the usual manner, and are encircled by the

Fig. 37.

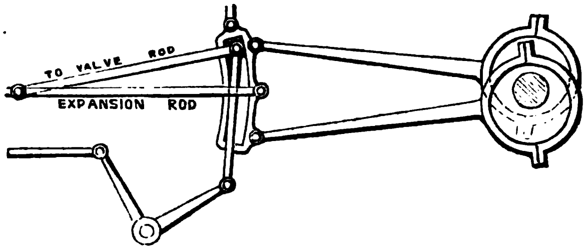


Charlton's Double-Slotted Link Motion, with Single-ported Main and Expansion Slide Valves, patented in the year 1856.

eccentric bands, which are firmly secured to the eccentric rods, the ends of which are forked and jointed to the double slotted link by pins. The eccentrics are fixed on the crank shaft, to correspond to a backward or forward motion of the engine. The link is suspended by a rod jointed to it by a pin; the other end of the rod is jointed to the bracket below in a similar manner. The bracket is permanently fixed to any suitable part of the framing or foundation plate, or to any suitable part of the boiler or engine. This rod keeps the link in proper position, but at the same time it is capable of vibrating while being actuated by the eccentrics through their straps and connecting rods. In the slot of the link a block is fitted; the sides of the link and block are flush, or nearly so. The connecting rod has both ends forked—in the same plane,—one end of which spans the link and embraces the block, and is jointed to it by a pin, which is passed through them. The other forked end of the rod is jointed also by a pin to the valve spindle, for the purpose of giving motion to the slide valve, which has ports—one at each end—which are formed right through from front to back. The valve ports correspond with ports in the cylinder face, the steam ways of which lead to their respective ends of the cylinder. The cylinder ports are nearer to each other than those in the valve, to allow space for the stroke. The expansion valve is formed hollow, and has two ports in its face to correspond exactly with the ports or passages in the main valve; a space is formed between the face of the expansion and main valves, to allow the exhaust steam to pass freely between them, and to be in communication with the exhaust steam chest, which is a space surrounding the valves completely, excepting at the parts where their faces touch. In the centre of the back of the expansion valve a supply steam port is formed: this communicates with or rather branches off to the ports in the face of the main valve.

Fig. 38 is a modification of the link motion previously described; all the parts being the same excepting the connection of the expansion valve rod with the link, which is at the centre of the back of the link instead of to a block working in an extra slot, so that the extra hand gear and rods can be omitted. The link is suspended at the top in this case, instead of at the lower end, as in Fig. 37.

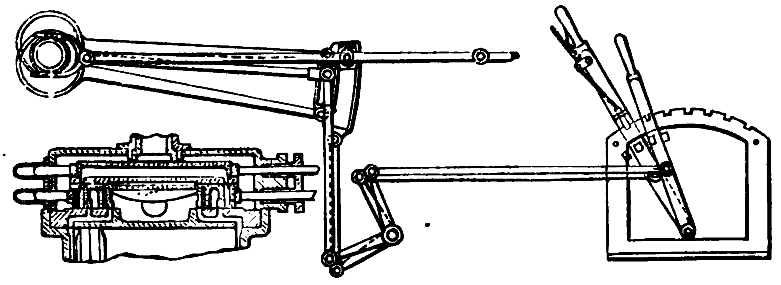
Fig. 38.



Charlton's Link-Motion for working the Main and Expansion Slide Valves, patented in the year 1856.

The next illustration, Fig. 39, is an arrangement of the double slotted link, which is *shifted* by rods and levers that are fixed by means of pins and catch plates—those previously described being fixed links—

Fig. 39.



Charlton's Shifting Double-Slotted Link-Motion, with Double-ported Main and Expansion Slide Valves, patented in the year 1856.

but the mode of shifting the slide blocks in the slots of the links is as in Figs. 37 and 38. In this arrangement the link is shifted on the block to fit it for a forward or backward motion; while to work or set the parts to work the expansion valve the block is shifted in the slot, and kept in any desired position by a small catch or projection, formed on the handle, let into notches formed in a segmental catch plate attached to the reversing handle, which is held by the catch plate. A rod jointed to the block by a pin, leads in a direction toward the crank shaft, which it spans or partially surrounds. Near the forked end of the rod another rod is jointed, which works the valve by being connected to the valve spindle.

Below the eccentric rods is a longitudinal section of another modification of the valves applied thereto; the main valve has *two* steam ports in each end through it; the cylinder has a corresponding number of ports, two of which open into the steam ways or passages to each end of the cylinder; the expansion valve, having a similar number in its face, which is fitted on the back of the steam valve.

About this date, 1856, the idea of improving or simplifying the link-motion was vigorously exerted, and the principle of Williams's link eccentric-band, as illustrated by Fig. 20 on page 22, was again revived, and that too by an important member of the now well-known firm of Sharp, Stewart, & Co., of Manchester. Mr. Stewart, and his friend Mr. Hope, of the same place, patented, in 1857, their "improvements in valve gear for stationary and locomotive engines."

They obviated the use of the *curved* or Stephenson link by the adoption of a *straight* link, either slotted or solid, as best suitable for certain positions of the valve gear; and the principles of their mechanical arrangements are, that they proposed to hang or support the straight link in the same manner as the ordinary stationary reversing link, and in connecting the sliding block, by a rod or link, with the end of the lever or arm from the reversing shaft, usually employed to move the valve connecting rod: the position of the reversing arm being so arranged, that when in the centre of the arc of its motion the sliding block will be in the middle position of its link; also, in jointing the valve connecting rod to the connecting rod attached to the sliding block of the link, at a distance from the point of connection or joint of the rod and sliding block. With this arrangement the valve connecting rod partakes of the motion imparted to the rod connecting the arm of the reversing shaft and the sliding block, not only that motion traversing the block along the link, but also that due to the curve of the arc described by the end of the arm of the reversing shaft, but of the latter motion it only receives a diminished proportion, causing the joint of the valve connecting rod to move in a curve practically equivalent to that which would be required in the ordinary curved stationary link.

The curve required is obtained by adjusting the length of the arm from the reversing shaft, and the distance of the joint of the valve connecting rod from the point on the sliding block. When the valve connecting rod is jointed to the link connecting the sliding block and arm from the reversing shaft at a point between the joint of the sliding block and arm of the reversing shaft, the curve described by the end of the valve connecting rod will have its concave side towards the reversing shaft; but if the point of attachment of the valve connecting rod is on the opposite side of the joint of the sliding block, the curve made by the end of the valve connecting rod will have its convex side towards the reversing shaft.

It will be obvious, from what has been stated, that the rod connecting the sliding block and arm of the reversing shaft becomes a lever, through which the movements of the link are transmitted, which movements will be consequently increased or diminished, according as the valve connecting rod is attached to it on one or the other side of the joint on the block; that is, according as the lever is made one of the second or third kind. This will necessarily have to be taken into consideration in the proportion of the ports and throw of the eccentric or eccentrics. The eccentric or eccentrics are set, and the link is suspended or sustained, so that when the sliding block is in the middle position upon its link, the valve connecting rod will be perpendicular to the link.

Next as to regulating, reversing, and transmitting the motion for working the valves. The general mode to accomplish that consists in a lever having two or three arms combined with a crank, or radius pin, or an eccentric, one arm of the lever being connected with the crank, radius pin, or eccentric, the fulcrum of the lever being so arranged that it can give way to the rectilinear motion imparted to it, the eccentric, crank, or radius pin being also arranged in a certain position relative to the crank or piston of the engine; and the combination and arrangement of mechanism just referred to will produce a motion to work the valve of a steam engine so as to rotate its crank in either direction, and will also give motion to a valve having lap, that is, one which extends over the steam ports when in the central position, so as to work the steam at various grades of expansion.

As a crank or radius pin and an eccentric are mechanical equivalents, and as eccentrics only are shown in the relative illustrations, further on, for working the lever, the word eccentric will hereafter only be used. We may add, however, that the lever is constituted by the clip of the eccentric and a reversing link or part of one combined together, the eccentric clip forming one arm of the lever, and the link or part of the link the other one or two arms thereof.

The eccentric is placed on the crank shaft of the engine, or on a shaft connected with the engine, driven by it uniformly with the crank shaft. The position of the eccentric in relation to the crank or piston of the engine is obtained as follows:—Set the engine with the piston at one end of its stroke, place the valve connecting rod or slide block in the central position of its link, in a line with the fulcrum of the link and centre of the shaft upon which the eccentric is placed. In this position, if the eccentric is rotated, the valve will receive a certain amount of traverse; and the correct position of the eccentric is that in which the valve will have nearly arrived at one extremity of the traverse, when the piston has arrived at one end of its stroke, and that in which the valve travels in the opposite direction to the piston. In other words, arrange the eccentric so that when the valve connecting rod is in the position before described, the valve and piston will nearly simultaneously arrive at the ends of their strokes, and so that the valve will uncover the proper steam port for the next stroke, to the extent of the lead allowed to it.

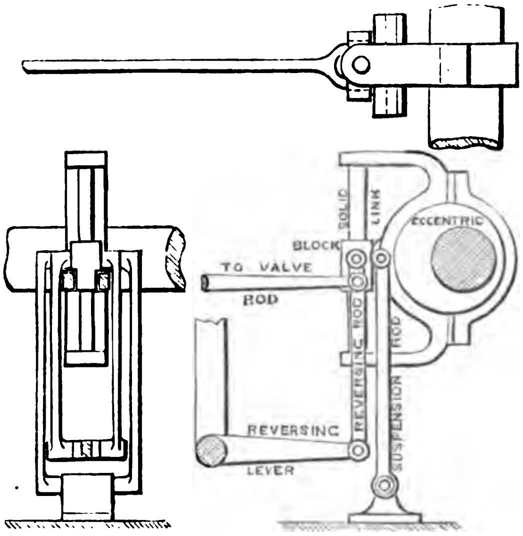
The radius of the eccentric must be a length equal to the sum of the length of the lap and the lead of the valve—that is, equal to the extent of the valve over and beyond the edge of the steam port when in its central position, and the space of the steam port to be uncovered at the commencement of the stroke—when the motion is taken directly from the slide block of the link to the valve, so that it will receive the same amount of motion as the sliding block. But if the motion of the sliding block is not given directly to the valve, but is transmitted through levers which increase or diminish it, then the preceding rule as to the radius of the eccentric will not apply: the eccentric in such cases must be of such throw as will, when acting through the levers employed, place the valve in the proper position at the end of the stroke of the piston, this being tested by the motion taken from the middle position of the link, in the manner described for setting the eccentric.

The proportions of the lengths of the arms of the lever, or clip and link combined, are about equal, but when the throw of the eccentric is fixed upon, or the lap and lead of the valve is fixed upon, and an increase of motion in the valve is required, it is obtained by making the arms of the lever, represented by the link, longer than that arm of the lever represented by the eccentric clip. It will be obvious that the lever or link has a compound motion, derived from the direct and angular motion given by the eccentric, that part of the link at the fulcrum partaking solely of the direct motion, the angular motion increasing as the distance increases from the fulcrum, and it will be found on examination that the angular motion in one direction is a little less than that in the other direction, and would consequently give a little more admission of steam on one than on the other side of the piston; but this is compensated by means similar to those employed to attain this object in ordinary link-motions, that is, by causing the block to slide on or in the link as it moves backwards and forwards, so that the block will go further from the fulcrum of the link as it travels from that side, which, but for this compensation, would have most admission to that side which would have the least admission, which is accomplished by arranging the position of the reversing shaft, so that the fulcrum of the rod to which the valve connecting rod is attached is on one side of the centre line of the reciprocating motion imparted to the valve connecting rod, namely, on the opposite side to that which is to receive the extra or compensating movement.

In engines which do not require reversing, but only a variable travel of the valve, and where the position of the block in the link is regulated by a screw, the admission of steam to the cylinder on both sides may be equalized by placing the fulcrum of the radius bar sustaining the fulcrum of the link on one side of the centre line of its oscillations, namely, on that side opposite to that on which the extra movement is required.

Thus far the principles of this valve gear are explained, and we next illustrate and describe the mechanical arrangements that fulfil them. Fig. 40 shows a side and end elevation, also a plan of the valve gear with a straight solid link as applied to stationary engines The eccentric, solid link, block, suspension rod, reversing-levers, &c., are

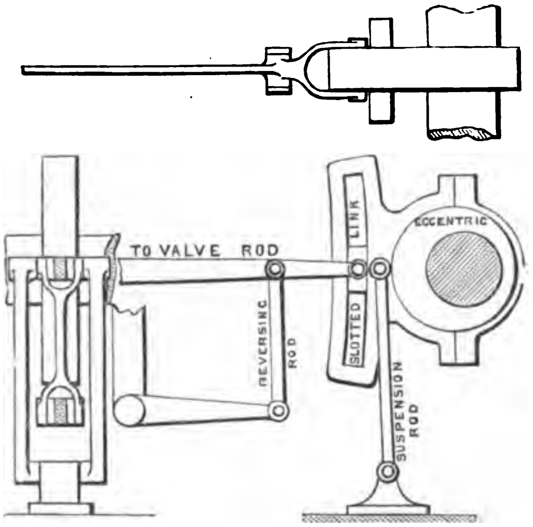
Fig. 40.



Stewart's Straight Solid-Link-Eccentric, Reversing Valve-Gear for Stationary Engines, patented in the year 1857.

all shown in position and connection. Fig. 41 is an arrangement with a *curved* slotted-link, also applicable for stationary engines.

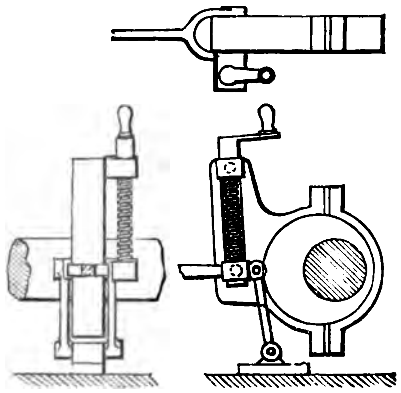
FIG. 41.



Stewart's Curved Slotted-Link-Eccentric, Reversing Valve-Gear for Stationary Engines, patented in the year 1857.

Fig. 42 illustrates an arrangement of slotted-link eccentric for non-reversing valve-gear, half part of a link only being required. In this case a screw is arranged as shown, having a handle, by which the slide block can be moved in the link, to vary the travel of the valve as required. The fulcrum of the radius bar in this and in the other modifications before described, is supposed to be held on a bracket secured to the bed plate framing, or some part of the foundation of the engine.

FIG. 42.



Stewart's Straight Slotted-Link, Eccentric Valve-Gear for altering the travel of the Valve for Non-reversing Stationary Engines, patented in the year 1857.

In applying this valve-gear for

reversing, to locomotive engines, certain arrangements are necessary to keep the fulcrum of the link in the same relative position with the crank axle, as any change of this position would affect the movements of the valve or link.

In the ordinary link-motion the link is sustained from the framing of the engine; but as the action of the eccentric rods is only in a horizontal direction, the vertical movements of the carriage or frame of the engine up and down, or to and from the axle, do not sensibly affect the motion of the link or valve, the length of the eccentric rods being great in comparison with the extent of the vertical movement of the carriage to and from the axle.

One method of overcoming the irregularities caused by the varying position of the axle in relation to the framing, is to fix the eccentrics on a separate shaft placed on a level with the crank shaft, and support it in bearings attached to the framing; this shaft being rotated at the same speed as the crank shaft by toothed wheels or by other arrangements.

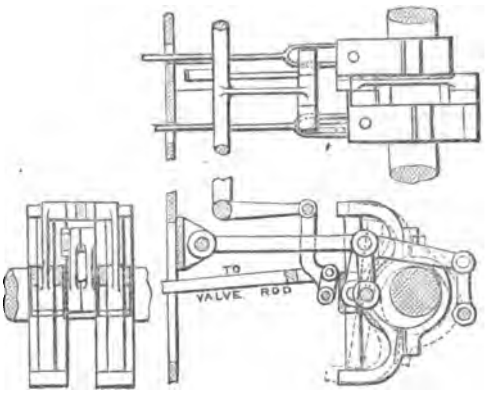
Another method is to make the crank shaft an intermediate shaft, or one not having any wheels attached, the power of the engine being conveyed to the driving wheels by coupling rods or other means.

A third arrangement is, by supporting the fulcrum of the sustaining link on a bracket resting upon or embracing the crank shaft, the bracket being prevented from turning or moving out of the position fixed upon, by guides attached to the framing, which allow it to give way only to vertical movements of the framing or axle; or this bracket is jointed to one end of the rod placed in a horizontal position, the other end of the rod being jointed to a part secured to the framing; or a part of the bracket embracing the axle is extended horizontally or obliquely to as great a length as possible, and the end is jointed to the framing of the engine. This arrangement reduces the objectionable motion in that ratio which the length from the fulcrum of the sustaining rod to the centre of the axle bears to the entire length of the bracket.

A fourth means is more especially applicable to inside cylinder locomotives, but may be easily adapted to those having the whole of the valve-gear outside, where the eccentrics are near together: and consists in arrangements whereby the clip of one eccentric is made to impart motion to a lever, so as to agree in time, direction, and extent, as near as required, with the movements of a part from the clip of the other eccentric, these two parts being connected together by a rod jointed to each, so that the forces acting upon the clip of one eccentric are counteracted by the forces acting upon the other; the centre of the lever being comparatively motionless under the action of the two eccentrics, and only requiring to be connected to the framing of the engine by a rod placed in a horizontal position, so as to prevent the links rotating with the eccentrics and to allow of the movements of the carriage of the engine.

In this arrangement the eccentrics and links are arranged as before described; a centre is adopted, upon which both radius rods for sustaining the fulcrum of the links oscillate. These radius rods are in length equal to the distance of the fulcrum of the link from the centre of the eccentric; one of them has an arm extending from it at a right angle, this arm being double the length of the radius rods; and to its end one end of another rod is jointed, of the same length as those sustaining the fulcrum of the links; the other end of this connecting rod is jointed to the back clip of the other eccentric, the joint on the eccentric clip being in a line drawn from the fulcrum of its link through the centre of the eccentric, and at a distance from the centre of the eccentric equal to the length of the radius rods. That centre upon which the radius rods oscillate, which sustains the fulcrum of the links, is the one which is comparatively motionless, and is the one attached by a connecting rod to the framing.

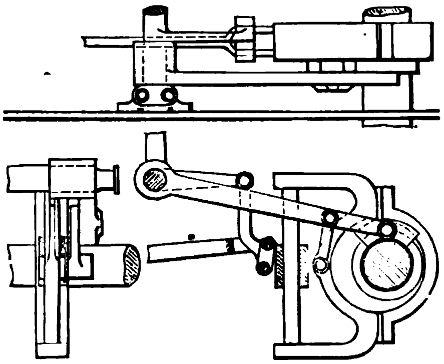
Fig. 43.



Stewart's Straight Solid-Link-Eccentric, Reversing Valve-Gear, for Locomotive Engines with inside Cylinders, patented in the year 1857.

The illustrations shown by Fig. 43, on the preceding page, are side and end elevations, with a plan of solid-link-eccentrics as applied to locomotive engines with inside cylinders. This arrangement is, that the radius rods sustain the fulcrum of the link, and the centre on which the sustaining rods oscillate, is the rod connecting this point with the framing of the engine. There is an arm extending at a right angle from the sustaining rod of one eccentric, thus forming a lever or rod connecting the end of the arm with the back of the clip of the other eccentric. The slide block of the link, and the joint pin upon it, the reversing shaft, the arm or arms from it, the rod or rods connecting the arm of the reversing shaft and the sliding block, and the valve connecting rod, are all shown also.

Fig. 44.



Stewart's Straight Solid-Link-Eccentric, Reversing Valve-Gear, for Locomotive Engines with outside Cylinders, patented in the year 1857.

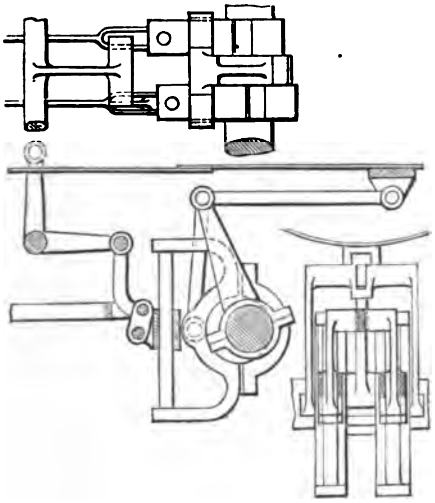
Fig. 44 shows the valve-gear applied to engines having their cylinders on the outside of the framing. In this case an arm is centered on the reversing shaft; the end of this arm is jointed to the segmental piece that fits and enters a circular groove formed in the side of the eccentric, and the sustaining rod is connected to this arm.

Fig. 45 has reference to inside cylinder engines. The bracket embraces the crank shaft, to which is connected the sustaining rod; and another rod is jointed to a bracket on the under side of the boiler.

Fig. 46 is a plan and a side view of the details of the straight solid link. In these views the link is represented as a round bar, having a sliding block bored to fit properly upon it, the slide block being made so as to joint with the valve connecting rod, or the rod connecting the end of the arm of the reversing shaft with the slide block represents the ends of the eccentric rods which connect with the valve rod.

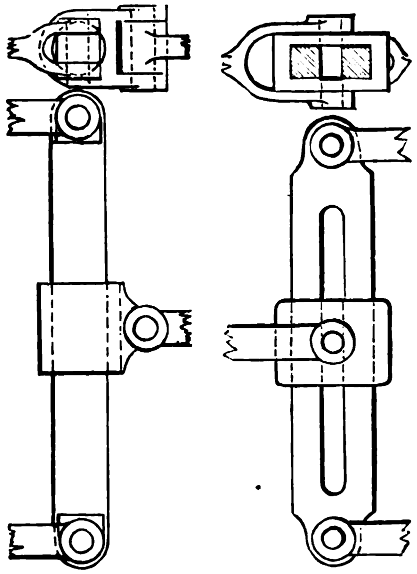
In the modification shown by Fig. 47, the bar is a parallelogram in section, and the sliding block has a hole of corresponding form, a slot being made in the link equal to the length of the traverse of the sliding block for the pin, which forms the centre upon which the valve connecting rod, or the rod connected to the reversing shaft arm is jointed; the pin passing through both link and sliding block. These links, when used in connection with two eccentrics, are suspended in the same manner as ordinary stationary link motions, that is, either from one end or from the centre, in which case a piece is added to one or both sides, with a pin for the connecting rod.

FIG. 45.



Stewart's Straight Solid-Link-Eccentric, Reversing Valve-Gear, for Locomotive Engines with inside Cylinders, patented in the year 1857.

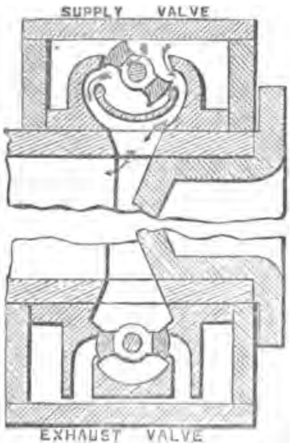
FIG. 46. FIG. 47.



Stewart's Straight Solid and Slotted Links and Blocks, patented in the year 1857.

Valve-gearing had a rest from the last date mentioned until 1860, when Mr. Newton, of London, received a communication from New York, America, to patent in England for Messrs. Crosby, Savage, and Stearns, the valves and gear now to be described. These supply and exhaust valves—showed opened and closed—are illustrated by Fig. 48, and are each composed of two eccentric segments, which may be united at one end or at both ends, and are provided with a journal at one end or at both ends, to work in a suitable bearing or bearings in the end or ends of the valve box, or in the side or sides of the steam chest, which contains the valve seat. The faces of the two segments are described from two different centres, which are equidistant from, but on opposite sides of the centre of oscillation of the valve. The opening through the valve extends nearly from one end to the other between the two eccentric segments. The valve thus constructed may have its sides parallel with its axis, or be made of tapering form. The seat for this valve has two faces, which correspond in shape with the faces of the valve, so that the valve may fit steam tight therein, and in each seat there is a port. It was proposed, generally to make the seat in a box, which can be inserted within the steam chest or other place where the valve is to be used, so that it may be removed therefrom with facility. In applying these valves to a steam engine, a set of four is necessary, viz., two for supply and two for exhaustion; the supply valves being arranged on one side and the exhaust valves on the opposite side of the cylinder. The valve boxes which contain the supply valves have a somewhat different arrangement of passages in connection with their ports from the arrangement in the boxes which contain the exhaust valves. The direction in which the steam passes through the valves, ports, and passages, is indicated by the arrows.

FIG. 48.

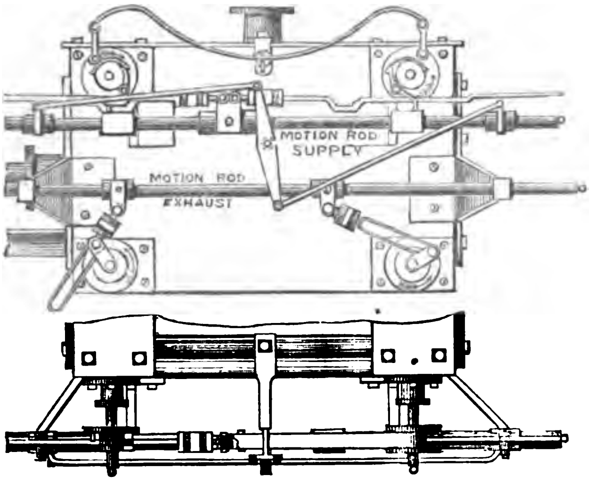


Crosby's Oscillating Equilibrium Segmental cut-off and exhaust Steam-engine Valves, patented in the year 1860.

It will be readily understood by reference to the supply valve represented as open, that as soon as the valve is opened in the slightest degree it is entirely surrounded by steam, and is therefore perfectly balanced. It is obvious also, that as the valve opens, its faces leave the seats, and it is only while the valve is closed that it touches the seats, and hence it works without any friction but that of its journal or journals, which is inconsiderable, and without any wear of its faces. It may be mentioned, also, that the pressure of the steam on the excess of surface presented by the sides of the segments of the valve will tend to keep the valve closed tightly. This excess of surface is, however, so slight, that the pressure upon it causes comparatively little resistance to the opening of the valve.

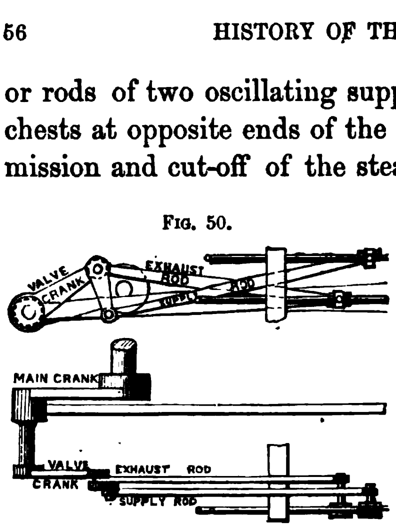
The gear for working these four valves is illustrated by Fig. 49, in elevation and plan. The cut-off gear is over that for the exhaust valves, and both consist of an arrangement of levers, rods, and shafts, in connection with cranks or levers on the main crank shaft, which latter are shown by Fig. 50 on the next page. The following is a description of the whole of the details and their relation to each other :—The cylinder of the engine is furnished with a square casing. The steam pipe on the top admits steam to both of the two steam chests, on which are the stems

Fig. 49.



Crosby's Valve-Gear for the Oscillating Valves shown by Fig. 48, patented in the year 1860.

Fig. 50.



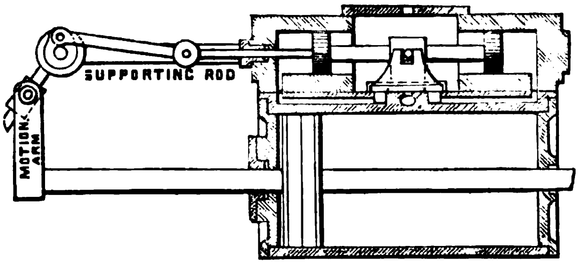
Crosby's Crank Motion in the place of Eccentrics for working the Valve-gear illustrated by Fig. 49, patented in the year 1860.

or rods of two oscillating supply valves, fitted to ports in the two steam chests at opposite ends of the cylinder; one of the valves effects the admission and cut-off of the steam at one end, and the other at the other end of the cylinder. Each of the stems or rods has secured to it, outside of its steam chest, a plate having a boss on its outer face, and these plates are connected by links with opposite ends of a strong spring, which is held by a bracket secured to the cylinder, so applied as to exert a constant tendency to turn each plate in the direction indicated by an arrow upon it, so as to close its respective valve, and each valve, if not of such construction as to be prevented from moving in the direction in which it closes further than is necessary to close it, must have a stop applied, to prevent such further movement. Each of the plates has attached to it, outside of its boss, a lever-like "dog," which is capable of swinging freely on the pin by which it is attached; and each of these dogs has applied to it a spring which is attached to the boss of its respective plate, and which acts upon it in such a manner as to press the upper end of it towards the boss, and through the lower end out therefrom. These dogs are applied on the sides of the bosses of the two plates, which are opposite each other, and are arranged in such a manner, that when pressure is applied to the toes of the dogs, to cause them to force the other ends of the dogs into contact with their bosses, it tends to turn the plates in the opposite direction to that in which the spring tends to turn them, and therefore to open the valve. The motion rod, arranged below the plates, is parallel with the piston rod of the engine, and with a line passing through the centres of both stems or rods working in guides, in which it is fitted to slide longitudinally. This motion rod derives a reciprocating rectilinear motion from a lever or crank carried by the crank shaft of the engine, by its being connected with the lever by means of a connecting-rod, the lever being so arranged relatively to the main crank pin as to give the rod the lead for the valve, to cause it to commence its stroke in either direction before the commencement of the stroke of the piston in that direction. A block is firmly secured to the motion rod, and having attached to it by two pins above the rod, one end of each of two similar bars, each of which bars is supported at some distance from its other end on one of two rollers, each of which rollers is fitted to one of two blocks. These blocks are fitted to slide upon the rod, and are connected by two rods, one for each, with opposite arms of a lever, which is arranged to work on a stationary fulcrum, for the purpose of adjusting the position of the blocks. The two bars which are used may be termed catch bars, are free to work vertically, or in a plane parallel with the face of the plates on the pins, and are straight, with the exception that each has a recess in its upper side, and has, some distance further from its pin, a step on its under side. These bars move along with the motion rod, and in such movement work between the plates and upright guide pins, which are secured in the guides.

It is obvious, from the two illustrations that have been just illustrated and described, that complication in relation to valve-gear must have been deemed a superlative accomplishment by the inventors; for they evidently strained all means possible to make complication—instead of simplicity—perfect in their arrangement; so much so indeed, that nothing, it would appear, could be added to what was proposed, either for assistance or improvement. They forgot, however,—*i. e.* if they knew—that the more simple the arrangement of any kind of mechanical contrivance is, the more perfect its action will be; or similarly, as in describing anything, the better the person who explains it is informed, the fewer words he will use to make himself fully understood.

In the beginning of the year 1862, a Mr. Steele applied for, and did get, a patent granted for his idea of what the most simple valve-gear should be. His arrangement is illustrated by Fig. 51, which is a longitudinal sectional elevation of the entire apparatus. In the illustration is shown the engine cylinder enclosing the piston and rod, also the valve casing, having attached to it at opposite ends two short piston cylinders situated in a line with each other, and parallel with the main cylinder. These cylinders are open to the valve chest at their inner

FIG. 51.



Steele's Steam Self-acting Valve-Gear, patented in the year 1862.

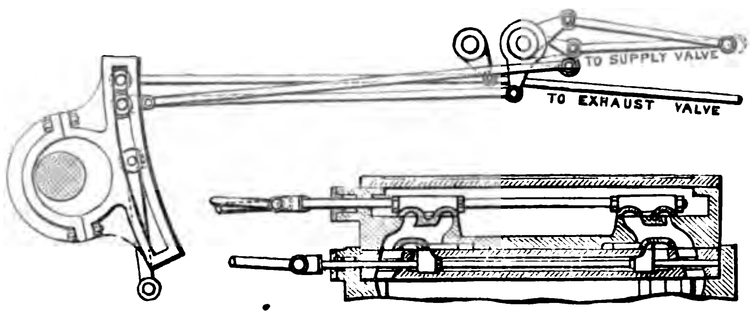
ends, but closed at their outer ends, excepting the latter, that has a stuffing box for the passage of the valve rod.

The main valve is of the kind known as the short "three-port" valve, with its seat having the usual arrangement of steam supply ports and exhaust port. At the side of the valve seat, and either parallel or in the same plane with it, is the seat of the secondary valve, which is like the main valve, only narrower, and works over an arrangement of ports that are narrower, as they are required for the passage of a very much smaller quantity of steam. These ports communicate by the passages to the outer ends of the cylinder, but the port that communicates with the main exhaust port may be by any other way brought into constant communication with the exhaust pipe.

The piston cylinders are fitted with pistons, one each, the inner ends of which are always exposed to the pressure of steam in the valve chest; the said pistons being rigidly secured to the valve rod. The secondary valve is connected with that rod by a pin secured to the rod, and entering between two lugs on the back of the valve, by which the said valve can be operated without any lost motion relatively to the rod. The main valve is connected with the rod by means of a pin in the rod and a slotted projection on the back of the valve, the slot being longer than the pin's diameter, to allow for a considerable degree of the lost motion of the rod with respect to the valve ; the object of which is, that while both valves are operated by the same rod, the secondary valve may always have the lead of the main valve. The valve rod is connected outside of the cylinder by a connecting rod with a short crank, which is loose on a fixed stud secured in a rigid arm, attached to the main cylinder, or in any other fixed support. This crank serves to limit the movement of the valves, and also to effect the first part of the movement thereof in either direction. The stud has also fitted loosely to it a lever, on which there is formed a fork, embracing the crank, but made so much wider as to permit the crank to make a quarter of a revolution of the crank within the said fork. The lever is fitted into a joint-piece, that is pivoted by a pin to an arm that is rigidly secured to the main piston rod.

Our next description is that of the " Allen " valve-gear, patented in 1862 in England, the inventor being a mechanic of New York, America.

Fig. 52.

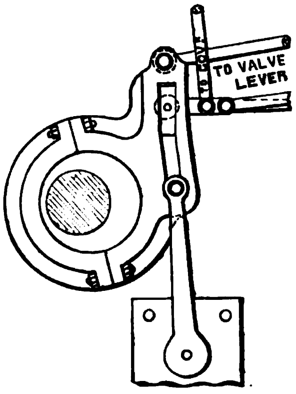


Allen's Reversing Link-Eccentric Valve-Gear and Double Valves, patented in the year 1862.

The illustration, Fig. 52, represents a side elevation of this valve-gearing for a steam engine in which the separate movements of the supply and exhaust valves are derived from a " link " operated by the revolution of a single eccentric operating those valves independently of each other, and capable of adjusting the points of cut-off of the supply valves as well as of reversing the motion of the engine.

To effect this, a slotted rocking lever or "link" is used, which is pivoted centrally by the fulcrum pin to the upper end of a sustaining rod that is hinged at its lower end to a fixed pin. This lever or link is attached to or forms part of the strap of the eccentric, which eccentric is secured to the main shaft of the engine. The link is slotted nearly through from end to end. In this slot are held two sliding blocks which can pass each other. The upper block is connected through the rod with an arm on a rock shaft, on which another arm is attached, connected through the rod with the exhaust valves. This block is fixed at a point in the link from which in connection with the arm or other gearing it will give to the said exhaust valves the correct motion. The lower block is connected to a rod, to which, a short distance from the link, another rod is attached. These two rods are attached to separate arms, secured to separate and independent rock-shafts, of which one passes through the other, so as to have a common centre of motion. On the end of the shaft to which the main vertical arm is fastened a lesser arm is attached, communicating through the connecting rod the motion to the supply valves on one end of the cylinder, and on the end of the shaft to which the lower arm is fastened, an arm above the other is attached, communicating through the connecting rod, motion to the supply valves on the other end of the cylinder. The positions of the arms working above and below the line running through the centre of the rock shaft and the slide valve rods are similar, and the manner of working the valves equal to the arrangement where similar arms are worked by means of a single eccentric. The curvatures of the slots in the lever or link in which the blocks are held and move, are circular. When the centres of the eccentric, the fulcrum pin, the shaft, and the centre from which the curvature of the slots is described, are on the same straight line, which will occur twice in each revolution of the shaft, the lever or link will be in such a position that the blocks may be moved from end to end in the slots in the link without altering the position of either of the steam or of the exhaust valves, but the position of the valves at one of these points will be advanced from the position at the other by the amount of the eccentric's throw. The eccentric is so set relatively to the engine crank that these said points will coincide or nearly coincide with the commencement of each stroke of the piston ; and the laps of the valves are made such, that at one end of the said points the steam valve is about commencing to admit steam to the back end of the cylinder, while when required at the other end, it is about commencing to admit steam to the front end of the cylinder. The portion of the piston's stroke during which the steam valves will remain open, will increase in proportion as the lower block occupies parts of the link more remote from the fulcrum pin. The movement of the valve derived from the lower half of the link will cause the engine to run in an opposite direction from that derived from its upper half. The lower block from which the supply valves derive their movements being separated from and working independent from the upper block, from which the exhaust valves derive their movements ; any position of that block,—and consequently the extent to which "expansion" may be advantageously caused—will not interfere with the correct action of the exhaust valve, as would be the case if the motion of the steam and exhaust valves were taken from one and the same block or point in the slotted lever or link.

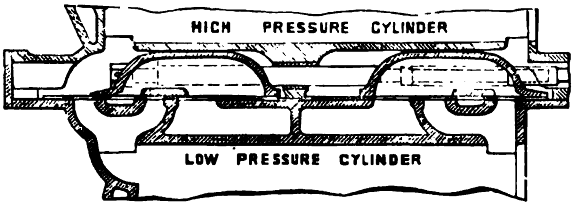
Fig. 53.



Allen's Non-reversing Link-Eccentric Valve-Gear, patented in the year 1862.

Fig. 53 represents a side elevation of an eccentric and connections for a non-reversing engine having a governor for regulating the speed. In this description of engine it is not desired to have the motion of the engine reversible, in consequence of which the upper or lower half of the link—as the case may require—can be dispensed with, and the link be made only with a single slot, in which the block that operates the steam valves is movable. The exhaust valves derive their motion in that case from a pin fixed in the solid part of the link. The governor rod is connected with the block, whereby the different degrees of expansion according to the load on the engine will be regulated.

Fig. 54.

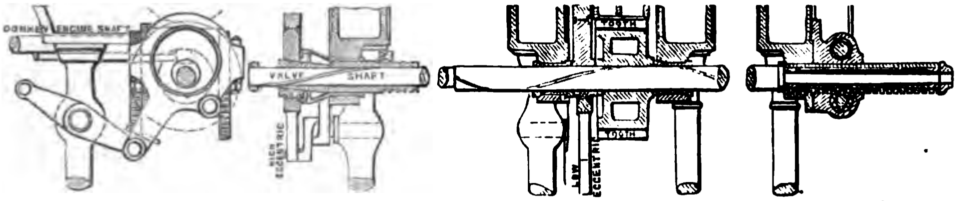


Elder's Multiple-ported Slide Valves for combined Cylinders of compound high and low pressure Steam-Engines, patented in the year 1862.

The next example that is worthy of record as an improvement in valves and gearing is Mr. Elder's, of Glasgow. His valves are shown by Fig. 54, which is for combined high and low pressure cylinders, acting as an intermediate-valve between them, the view being a longitudinal section showing the arrangement of the valves and cylinder. The steam, in passing from the high-pressure cylinder to the low-pressure cylinder, leaves the former by ports opening into two intermediate valve chambers. The valves are fixed upon the same rod, which passes from one chamber to the other through a gland, and they work upon port faces, each having an exhaust port and two inlet ports communicating with the low-pressure cylinder. One valve is shown as having uncovered one of the two ports into the low-pressure cylinder, the other port next to it being covered by a plate crossing the cavity of the valve. The other valve is necessarily in the opposite position, both ports being open to the exhaust port, whilst the covering plate occupies the bar between the two ports. These valves, in either direction of their motion, travel only so far as to uncover one port to admit steam across from the high-pressure cylinder to the low-pressure cylinder, whilst the same travel uncovers the two ports at the opposite end of the cylinders for final exhaustion. The travel of the valves is thus reduced to a minimum, and also the loss of steam by clearance, the valves and valve chamber being shaped so that the former as it were fill up those ends of the latter towards which they move in cutting off the steam.

Besides that, Mr. Elder patented at the same time an arrangement of valve-gear—of which Fig. 55 is a sectional elevation and an end view —as arranged for engines for driving paddle-wheels. The valve shaft is driven by means of a toothed wheel connected to it by a straight groove and feather, so as to admit of the shaft's movement endways, and this wheel is in gear with an intermediate wheel over it, which last is driven by means of a wheel fast on the main shaft, not shown. The valve shaft wheel, and the eccentric at the side for working the low-pressure valves, are mounted on the same shaft, between bearings which keep them from being moved endways when the shaft is so moved, and the eccentric is connected to the shaft by a spiral groove and feather, in consequence of which the endway movement of the shaft alters the position of the eccentric relatively to the wheel, and therefore to the crank shaft. For the purpose of moving the valve shaft endways, there is fitted on it at the right-hand end between collars, a loose tubular piece formed with rack teeth, with which there gears a pinion on a shaft driven by a small donkey engine. This arrangement of valve-gearing relates also particularly to the mounting of the "high" eccentric at the left hand, which works the valves of the high-pressure cylinders. Such eccentric has hitherto been connected directly to the valve shaft by a spiral groove and feather, as in the case of the other eccentric; but by this modification it is mounted upon an elongated tubular boss, shown in section also. This tubular boss is fitted upon the valve shaft with a

Fig. 55.



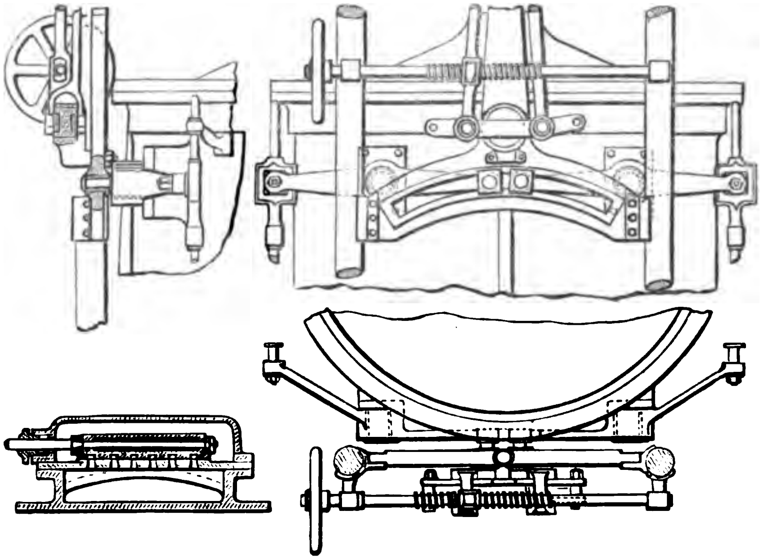
Elder's Expansion-Gear for Oscillating Paddle-wheel Engines, patented in the year 1862.

spiral groove and feather, so that its position in the circle relatively to the main cranks may be altered by the endway movement of the valve shaft simultaneously with that of the "low" eccentric. The tubular boss is formed externally with a cylindrical surface disposed obliquely to the valve shaft, and the high eccentric is bored with corresponding obliquity to fit on such oblique part, whilst its proper rectangular position is retained relatively to the shaft. The axis of the oblique piece is in the line passing through the axis of the shaft and through the centre or axis of that eccentric, so that an adjustment of the oblique piece through the eccentric varies the eccentricity or throw of the latter. This endway adjustment of the tubular piece is effected by means of a pinion, the teeth of which gear with teeth upon the piece, such teeth being cut round the piece to admit of the latter revolving without getting out of gear. The pinion is fixed on a shaft, which may be actuated by a hand wheel or other convenient means to effect the adjustment when it is wished to vary the throw of the eccentric, and consequently the period of cut-off. To keep the eccentric in its place, it is formed with a collar, which is embraced by grooved sleeves formed upon the brasses of the bearing in which the parallel portion of the tubular boss turns, and which supports that end of the valve shaft.

Directly after Mr. Elder had carried out his ideas as to the arrangement of perfect valve-gear, for oscillating engines in particular, Mr. Caird stepped forward with his invention, which was also specially adapted for oscillating engines. The details were contrived as follows:—The working steam cylinder is formed or fitted with separate and distinct valve faces; two, for example, for the main working steam slide valves, and two for the expansion slide valves on the steam belt. These valve faces, and consequently their corresponding valves, are disposed two on each side of the main trunnion on which the cylinder oscillates, that is, there is one main steam slide valve and one expansion valve on each side. The expansion valve is placed nearest the trunnion, so that it is between the trunnion and the main steam slide valve, and it is worked by a double lever arm from the link. This arrangement of the valves forms a good balance, and it enables the expansion to perhaps be carried out in a much more effective manner than can be accomplished acccording to the usual plan. To a segmentally slotted bar or cross-head piece, similar to that ordinarily employed for the communication of the eccentric's motion to the main slide valves, without any derangement from the oscillatory action of the cylinder, there is attached at the centre a cranked stud. This stud is bolted in laterally, and is cranked upwards, terminating in a large eye. This eye is bored out horizontally to embrace a traversing bush cylindrical in external form, but recessed laterally on each side, or formed with top and bottom shoulders to fit into the expansion lever link. This link is composed of two plain bars or curved segmental pieces bolted together, with a space between them for the traverse of the bush therein. It is from this stud as a centre that the motion of the eccentric is conveyed to the valve. One end of the link is joined in the usual manner by a fixed stud to the lower end of the eccentric rod from the main shaft, and the link thus receives the vibratory action necessary for the operation of the valve. The opposite end of the link is similarly jointed to the lower end of a *pendent* radius rod or bar, the upper end of which is fitted with a ring to embrace a concentric collar or shoulder on the main shaft, or fixed to a stud placed as near the centre of the shaft as possible: thus this rod has no longitudinal traverse motion, and its lower end forms the fixed supporting centre for the link to work upon. This lower end is fitted with an adjusting screw, spindle, lever, and link movement, or other adjusting arrangement, so that it can be set in or out from the main vertical centre line of the cylinder, and thus vary the effective throw of the link, and consequently alter the expansive action of the valve. This system of valve-gear is applicable to all classes of steam engines and valvular apparatus, and it is available as well for the main slide valves as for separate expansion valves. The adjustable radius bar always keeps the centres correct, and forms a steady fulcrum for the link motion, whilst its adjustment is so simple that the engines can be handled with great facility.

This arrangement, excepting the eccentrics, is shown by Fig. 56, in side and end elevations, also in plan. The steam cylinder, the belt, together with the supply and exhaust passages through the trunnions, are each arranged in the manner common to engines of this class. On each side of the trunnion through which the steam enters, there is arranged the expansion valve, shown in section under the end view, which regulates the admission of the steam to the cylinder. Each valve casing for it has fitted within it the valve face, as shown, as is also the position of the expansion valve and its connected spindle. To this part is attached the valve-rod, the upper end of which passes through an eye formed in the guide, which projects out in a lateral direction from the face of the cylinder. The prolongations of the valve rods are each formed with a boss or lateral enlargement at the

FIG. 56.

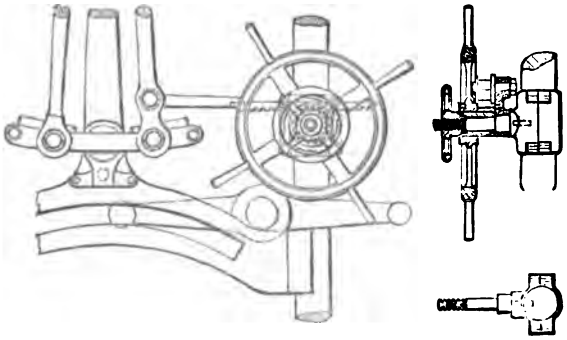


Caird's Link-Motion, Expansion-Valve and Reversing Gear for Oscillating Paddle-wheel Engines, patented in the year 1862.

central part, in which a bush is fitted, to admit of its being connected by means of a bolt and nut to the ends of the bent levers. These levers are each centred on a stud, the back plate of which is secured to a projecting part cast on the face of the cylinder. The inner arm of each of these levers extends towards each other, and terminates in a brass bush or block, so as to traverse easily to and fro in the segmental slot, which is formed in the bar or cross head. The cross head is formed with a prolongation that extends in an upward direction, the extremity passing through the eye of a guide, which is bolted to the beam of the framing, the lateral extremities of the cross head being bolted to guide brasses which partly encircle the columns of the framing. To the centre of the cross head is fixed a cranked stud, which is cranked in an upward direction, and terminates in a large eye. In this eye is fitted the traversing bush, which is recessed in a lateral direction on the front and back, or formed with top and bottom projections which embrace the expansion lever link, as shown in the end view in section. This link is composed of two plain bars or curved segmental pieces, which are bolted together at the extremities, leaving a space between them for the traverse of the bush. One end of the link is jointed to the lower end of the eccentric rod, the reciprocatory movement of which is communicated to the expansion valves. The other end of the link is joined in a similar manner to the *pendent* rod, the upper end of which is bolted to a strap that encircles a ring on the main shaft. Instead of this arrangement, the rod may be fixed to a stud arranged as near the centre or axial line of the main shaft as possible. A slot is formed in the lower part of the rod, in which is fitted a nut, and through this the horizontal screw works. This screw is supported in bearings, which project out from the columns of the framing, and on one extremity is fitted the hand wheel. By turning the hand wheel the screw is put in motion, which causes the rod to move in a lateral direction either to the right or left, according to the direction given to the hand wheel by the engineer. In this way the link is caused to move in either direction, so that it can be set to or from the vertical centre line of the cylinder, and thus vary the throw of the link, and so alter the expansive action of the valves to the extent that may be found desirable.

Another mode of arranging the mechanical details connected with these expansion valves is shown by Fig. 57, in side and end—sectional elevations. In this arrangement the lever with the cross head, cranked

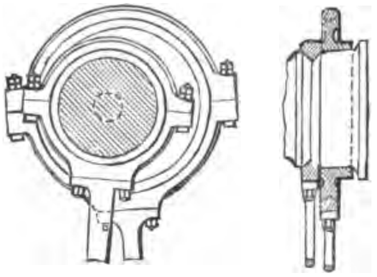
FIG. 57.



Caird's Link-Motion and Reversing Gear, patented in the year 1862.

stud, and link, are similar to the corresponding parts shown previously. The lower ends of the eccentric rod and the *pendent* rod are bored and fitted with brasses, which form the bearings for the link studs. The rod is jointed by a link to the horizontal rack, which is actuated by a pinion on the back of the hand wheel. This wheel is mounted on a stud which is bolted to the column of the framing: the inner part of this stud is formed with a shoulder to receive an eye, in which the stud of an antifriction roller is carried. This roller presses on the back of the rack, so as to keep it in gear with the pinion. The tubular boss of the hand wheel fits on to the cylindrical part of the stud beyond the eye carrying the roller, and outside this part the stud is screwed to receive the small hand wheel, the boss of which is screwed internally to correspond to the stud. The inner edge of the boss of this wheel is bevelled off, and it enters a corresponding part formed in the boss of the hand wheel. The valves are set to the required point of expansion by means of the hand wheel which moves the rack to and fro, and both are fixed in the position desired by screwing up the hand wheel: which wedges the boss of the wheel, and holds the parts securely. In this way the expansive action of the valves may be regulated and adjusted with the utmost ease and facility.

Fig. 58.

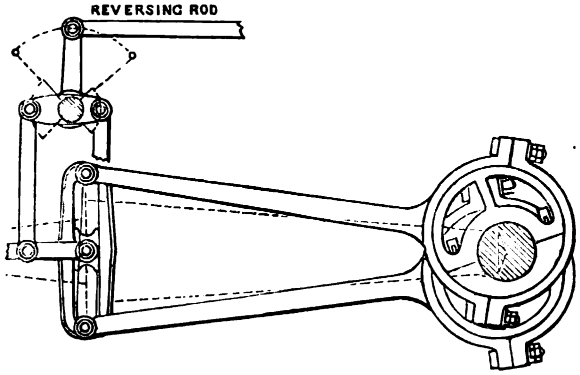


Caird's Eccentric and Ring for working and suspending the Link, patented in the year 1862.

The illustration, Fig. 58, is a side and sectional end elevation of the eccentric and concentric-ring, with their bands for working the motion last described, and illustrated by Figs. 56 and 57.

Link-motion at this date had reached an advanced stage of perfection. As for example, Allan had improved his straight link considerably, as shown by Fig. 59, which contrasts widely with that illustrated by Fig. 31 on page 35.

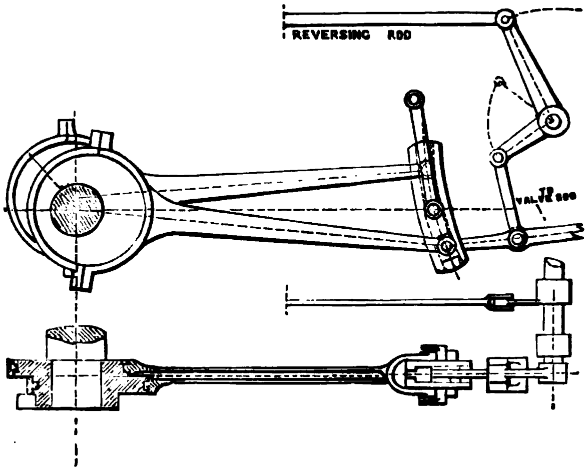
Fig. 59.



Allan's Improved Straight Link-Motion, exhibited in the International Exhibition in the year 1862.

Mr. Gooch also, now Sir Daniel, the well-known railway engineer, had modified his previous adoption of Stephenson's link by the arrangement shown by Fig. 60. The eccentrics are keyed on the shaft as usual, and actuate the rods in connection with the link, the convex side of which is turned from the shaft, instead of towards it, as with the "lifting" or Stephenson link. The Gooch link is formed of two bars very similar, as the original "Allan link" was, and is hung at the centre by a swing or radius bar on each side, so that the travel of the centre of the link, due to the motion of the eccentric, is always on the arc described by those bars. The block between the link bars is connected to the slide valve rod by a rod which is raised and lowered by levers and rods termed the reversing-geár, so that in this case the shifting of the block instead of the link starts, reverses, and stops the engine. As this arrangement is represented in plan and side elevation, it can be fully understood without further description.

Fig. 60.



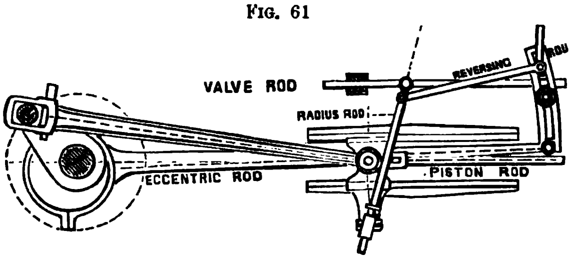
Gooch's Suspended Box-Link-Motion and Reversing Gear, patented in the year 1862.

The next example is taken from Dr. Zeuner's work on the link-motion, and was modified by Heusinger von Waldegg, a German engineer of good repute. This valve-gear is represented in side elevation by Fig. 61. Upon the centre of the driving axle, besides the crank, there is fixed an eccentric, the eccentricity of which forms a right angle with the centre line of the crank.

The eccentric rod imparts to the link an oscillating motion, that terminates at the fixed pin supporting the link. The link has a curved slot, in which the sliding block, which is connected to the radius rod, can be moved up and down, by means of the lifting rod, in order to produce a variable expansion of the steam as required.

The radius, or reversing, rod is connected at its end to two levers, which at their upper ends are fastened by joints to the valve rods, whilst their lower ends move in sliding and vibrating bearings, formed with the piston rod's cross heads. Each lever has thus a very peculiar motion given to it; the one end moves with the piston rod backwards and forwards, while the other joint end receives from the link another oscillating motion, and the valve-rod joint is thus brought into such a motion as is suitable for working the valve, as experience has shown where practically carried out.

FIG. 61



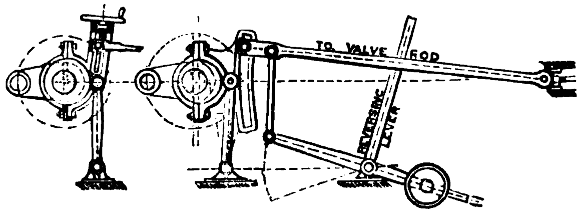
Heusinger von Waldegg's Single Eccentric, Fixed-Link-Motion, and Reversing Gear, as arranged in the year 1862.

A very simple fixed link-eccentric motion has been proposed by Pius Fink, also a German engineer, as shown in Zeuner's work, dating therefrom the year 1857, as illustrated by Fig. 62 on the next page. This is the single eccentric link-motion, the link being formed in the half-band of the eccentric and supported by a rod. A lever which swings from the fixed point is coupled to this link at the joint, so that the joint moves backwards and forwards almost on the centre line of the stroke, whilst simultaneously with the turning of the shaft, oscillating movements of the link take place from this point.

The radius rod, which is connected with the valve rod, is moved up and down in the link by means of the bell-crank lever, to which it is connected by the lifting rod. The engine runs then either in the one or in the other direction, according to whether the sliding block is placed below or above the dead point of the link; and, besides that, the shifting of the block governs the grade of expansion.

This valve-gear has especially been used for stationary engines, which have to work with variable expansion, but which have always to run in the same direction. For such cases only the one half of the link is constructed as shown in elevation at the left hand, and the sliding block is then fixed at any required point of the link by means of a screw and handle. The difference, *viz.*, whether the shifting of the radius rod is effected through a bell-crank by means of the connecting rod, or whether the block is fixed in the link by a screw, must be taken into consideration during any theoretical investigation; for the movement of the valve will be different in the two cases, because the slide block moves up and down in the link during its working between certain limits, in the first arrangement, but is fixed by the screw in the other.

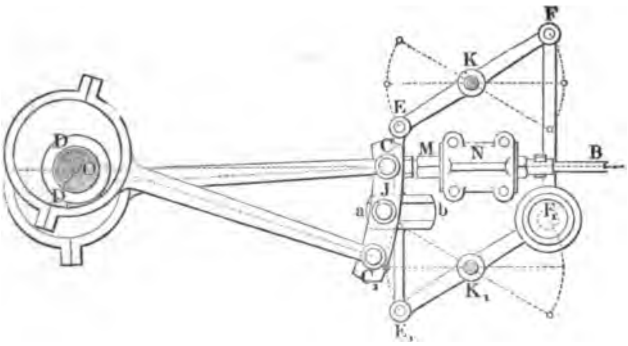
Fig. 62.



Pius Fink's Link Eccentric Motion and Reversing Gear.

It is obvious that in every case where the link is supported or hung by a rod, the forward and backward motion of that point of the link is a curve or arc, the radius of which is the length of the rod in question. To obviate that motion, and make the link to move in a straight line, the arrangement shown by Fig. 63 on the next page was arranged by Von Landsee. The parallelogram EFF_1E_1 is movable round the points K and K_1; the vertical links EE_1 and FF_1 move on the turning of the horizontal arms EF and E_1 F_1 in a direction parallel to each other, and the guide *a b*, which is fastened to the vertical rod EE_1 and is provided with a slot parallel to the centre line O B, will thus always occupy positions at which this parallelism remains unaltered. In the slot of the guide *a b* the centre pin J of the link moves backwards and forwards. The parallelogram, which is provided at F_1 with a counterweight, can be moved from the footplate on which the driver stands, in the same manner; the shafts marked with KK_1 are for both levers identical in application. MB represents the valve-rod and N its guide, the link appears as lowered: and as the eccentrics are arranged, the engine, when the different parts are similar, as shown in the figure for a locomotive, will run forwards.

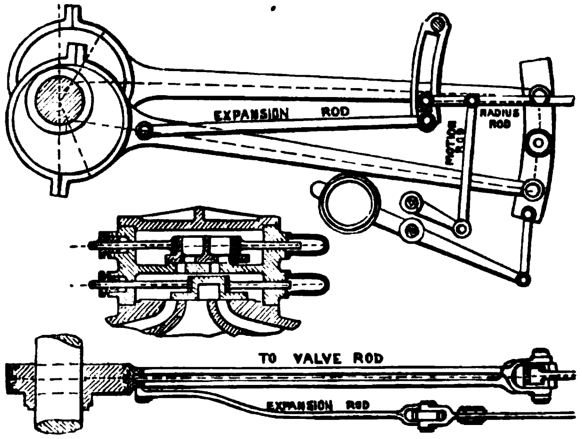
FIG. 63.



Von Landsee's Link-Motion, with parallel suspension bars.

Besides the arrangement of link-motion by English engineers, that we have already illustrated, for working *two* slide-valves, one over, or on, the other—the under valve being for exhaustion and the upper for supply and expansion—the German engineers have proposed and adopted various methods, three examples of which we select from Zeuner's work. The first we refer to is by Gozenbach, as represented by Fig. 64 on the next page, in side elevation and plan, with the section of the valves between the two views. The links are the box and slotted kinds, and perform separate duties. The box link is in connection with the main or exhaust valve, which valve is only used for effecting either the forward or backward motion of the engine, or for bringing it to a full stop: this is produced by either fully lowering the link by means of the lever and the rod in connection, so that the forward eccentric only governs the valve-rod, or by fully raising the link, so that the valve receives its motion from the backward eccentric, or finally, by placing the link in its central position, so that the dead point of the link does not move the valve-rod, and consequently, on account of the certain regulation of the steam which takes place at this position of the link, brings the engine to a standstill.

Fig. 64.

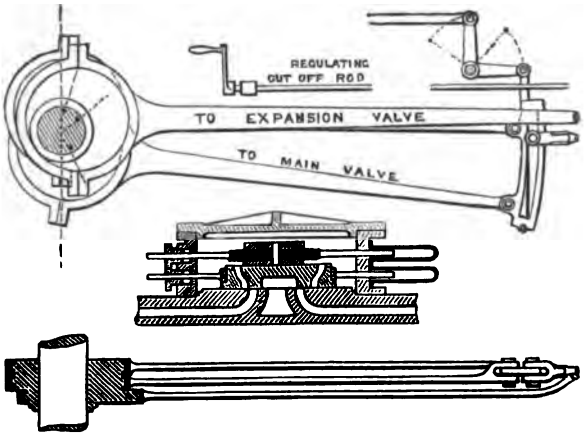


Gozenbach's Separate Link-Motions with only two Eccentrics for working the double Valves with a Divisional Seating.

But the other positions of the link are not employed in the present valve-motion to govern the movement of the valve, so as to produce a *variable expansion*, as is the case in the general system, for such variable expansion is here produced by the supply or expansion valve, which receives its motion in the following manner. The expansion rod, which is fastened at its end to the slotted link, is connected through a pin with the band of the backward eccentric, and is thus moved backwards and forwards; therefore this link swings upon the fixed point above it, and thus receives an oscillating motion. The end of the radius rod moves up and down in this link, and may be fixed in a certain position by means of the lever and the motion rod; the radius rod is connected at its end with the rod of the expansion valve, so that the backward and forward motion of the block is transferred to the latter. Of course the nearer the block is to the fixed portion of the link, the less is the stroke of the valve. The main valve is a common valve, the outside and inside lap of which, however, is taken in the present case smaller than usual; but the expansion valve, which moves in a separate steam chest upon the cover of the steam chest of the exhaust valve, is a *gridiron valve.* If the slots of that valve coincide with the openings in the seating between the two steam chests, the steam enters into the chest of the main valve; and the expansion will begin as soon as the expansion valve shuts those openings. The slots in the expansion valve are generally a little larger than the openings in the seating.

The next German example we notice is by Meyer, and has *three* eccentrics, as shown, by plan and elevation with a section of the valves,

Fig. 65.



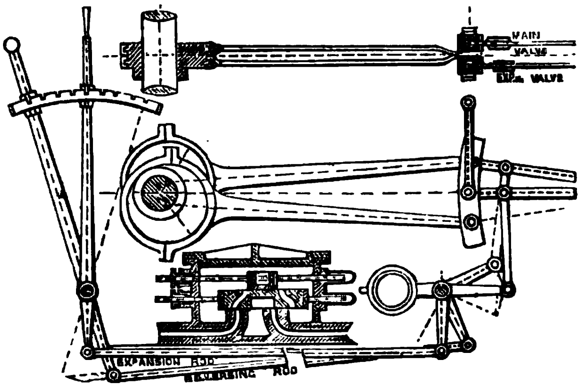
Meyer's Treble Eccentric Gear with Link-Motion for working the double Valves.

by Fig. 65. The arrangement of the gear is as follows:—The main valve is moved by means of a link on Stephenson's system, and the only utility of the link in the present instance is for the purpose of reversing or stopping the engine, which is produced by the use of the central point or the dead point of the link to govern the valve. This valve consists of a plate through which are two ports, and between them are the bars and the port for the release of the steam. These two outer ports move backwards and forwards over the ports of the cylinder, and allow the steam to enter into the cylinder through the latter ports, it being supposed that the expansion valve does not cover the corresponding port on the top. The expansion valve consists of *two* plates, which virtually form two screw-plates with right and left-hand threads, and are thus connected with the valve rod, which of course is also formed for a corresponding length with threads of the same kind. Thus if the valve rod is turned around, the two plates will, according to the direction of the turning, either approach each other or be moved farther apart. The expansion valve is therefore a kind of twin-plate, which may either be lengthened or shortened, by which means, as the figure on the preceding page illustrates, an earlier or later cutting-off of the steam occurs, and thus a variable expansion will be produced.

The turning of the valve rod for the variation of the expansion may be effected during the running of the engine by the following arrangement. The end of the valve rod has for a certain length a square section, and on this portion is placed a small pinion, this pinion not being fastened to the rod, but being kept in its place by some other means. The rod moves, during the motion of the engine, backwards and forwards in the pinion, without the latter taking any part in that motion. This pinion works into another pinion fastened upon the axle which carries on its end a small hand-crank. Of course this hand-crank is, in the case of locomotives, so placed that it may be easily reached by the driver. This description will now show that the turning of the crank produces a movement of the plates forming the expansion valve: a certain position of these plates, and therefore also of the hand-crank, corresponds to a certain grade of expansion. The expansion valve is generally moved by means of a special eccentric and an eccentric rod; the eccentric is fastened on the shaft, in this case, at an angle of advance of nearly 90°."

The third example that we have referred to is by Polonceau, and consists of twin links, but single eccentrics to each link, as illustrated by Fig. 66 in side elevation and plan, also a section of the valves and cylinder ports. The links are the box kind: their convex sides being turned towards the crank shaft, and are suspended by bars or rods that are fixed on a stationary centre or pin, and thus they receive an oscillating motion from the two eccentrics fixed on the crank shaft. The arrangement of these parts is therefore somewhat the same as used by Gooch. The sliding block for the main valve is by the radius rod moved in one link; similarly as illustrated by Fig. 60 on page 70; this radius-rod is connected with the valve-rod of the main valve, so that the latter receives its motion from the swing joint of that link.

FIG. 66.



Polonceau's Twin Single Eccentric Link-Motions and double Valves.

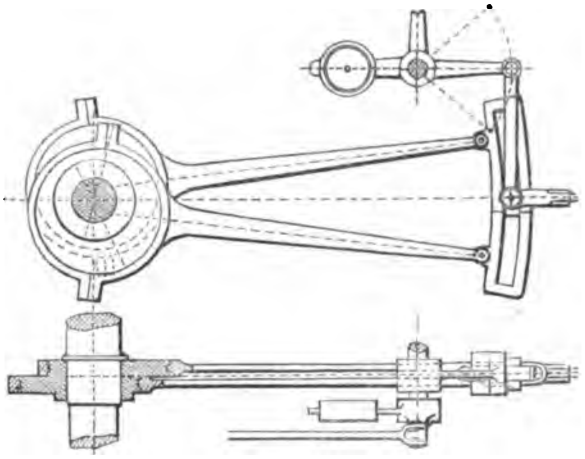
The sliding block, for the expansion valve, is by the other radius-rod moved in the other link; and this radius-rod therefore transfers the motion of the joint of this link to the expansion valve.

The movement of the two sliding blocks by means of the lowering or raising of the radius rods is effected by the driver by means of the reversing levers, the ends of which are connected by rods with the bell-crank levers, whilst the rods transfer the movement to the radius-rods, and thus the valves are shifted.

The reversing levers move in the quadrant guide, which is provided with notches, and in which the levers can be fixed at different positions, in the usual manner, by means of springs. The main valve is nearly of the same shape as that in Meyer's valve-motion, shown on page 75. The expansion valve, however, consists of a simple plate enclosed in a frame, but moves also on the top of the main valve.

Those six last examples portray the aptitude of the German engineers for modifications of link-motion; but while we pay them our compliments for ingenuity, we cannot extend them for simplicity, as in all cases complication has been particularly carried out rather than avoided. As for example, as a contrast, what can be more beautifully simple than our English link-motion as illustrated by Fig. 67. Here we have simplicity arranged with elegance, and both combined with perfectly equal action for the backward and forward motion of the engine; and *all* those accomplishments it must be remembered were invented and practised

FIG. 67.

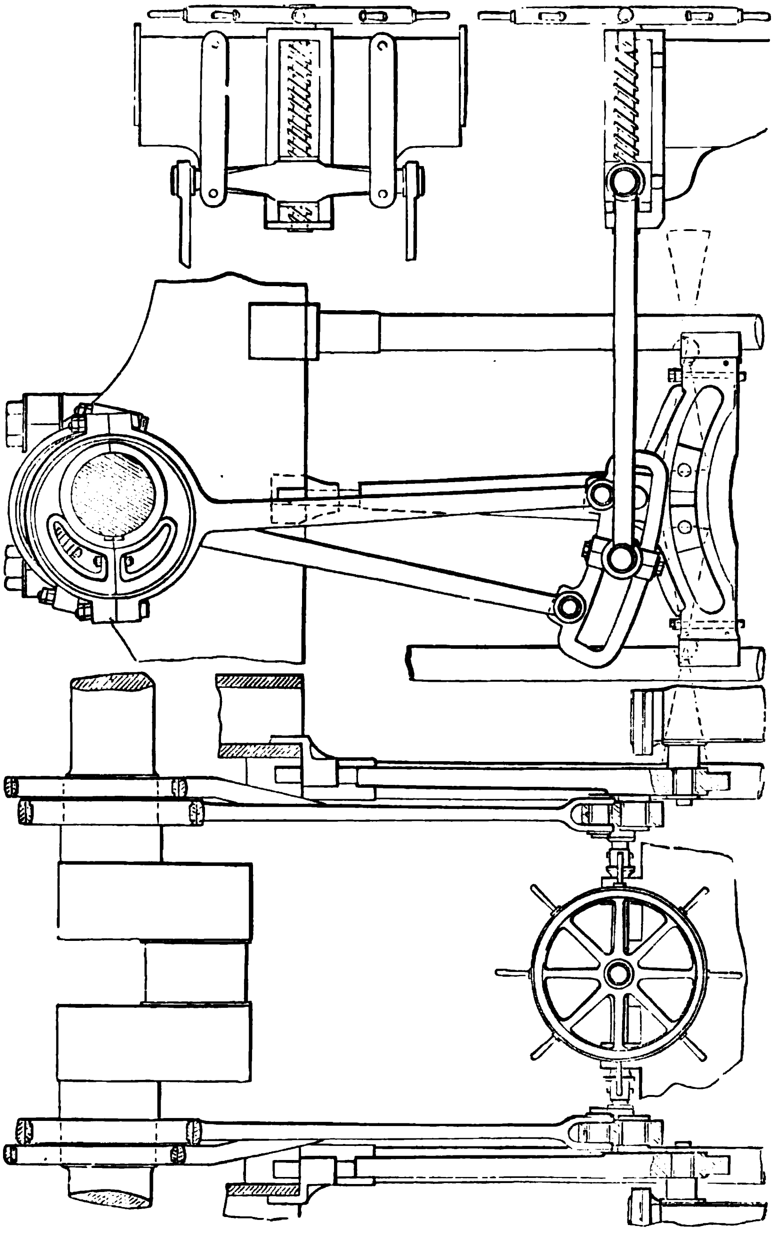


English Link-Motion, as universally adopted since the year 1843.

in England by Englishmen as far back as the year 1843. In mentioning this we may add our purpose is to place the laurels where they belong, without prejudice or national feeling.

We must notice next the marine-engine link-motion as arranged to the year 1862: treating first of the gear for oscillating paddle-wheel engines, and we may remark that the arrangement of the detail requisite to impart the motion to the slide-valve forms an important consideration with the marine-engine, and more particularly so when the oscillating type is dealt with. The cylinder vibrates, and also its appendages, and the main accomplishment is a vertical motion for the slide-valves, independently of their lateral motion. To produce this a sliding quadrant is requisite, and the efficiency of this detail depends on the curve of the slot. The correct shape of this curve is undoubtedly *semi-elliptical*, the lesser radius being at the extremities. For practical purposes, an uniform curve is usual, the radius of which is—the angular distance between the centres of the sliding-blocks and the trunnion, when the working levers are on the horizontal line. The illustration, Fig 68 on the next page, is an arrangement of " link-motion and starting gear " of a pair of oscillating engines constructed by Messrs. James Watt and Co. The eccentrics are in halves, connected by bolts; the rods being of the ordinary kind, with double eyes to clasp the link. The peripheries of the eccentrics are fitted with brass hoops with projections to suit the recesses formed in the bands of the rods, the hoops being also recessed on the eccentrics to prevent lateral movement. The link is the usual shape, with brasses in the eyes, adjustment being caused by cotters above the top brasses. The sliding quadrant is guided at the sides by semicircular brasses clasping the main columns, and adjusted by keys and set nuts; the guidance of the upper end is attained by a bracket, secured to the entablature. The " side elevation " shows the link thrown back, or at full-stroke for starting, the quadrant and the levers being at half-stroke, the latter being indicated by dotted lines only. " The end elevation " shows the links in section, also a portion of each of the quadrants, the cecentrics being represented as keyed on the intermediate crank shaft.

FIG 68.



End Elevation.

Side Elevation.

Plan of Starting-Gear.

Messrs. Watt's Link-Motion and Starting-Gear for Oscillating Paddle-wheel Engines, as used in 1862 and for fifteen years previously.

Next, attention must be given to the starting-gear. The main use of this gear is to raise or lower the slide-valves without the motion of the cranks, or steam pistons. Now, with the link motion as last illustrated, this is effected by moving the link forward or backward as may be required, which by the fixed positions of the eccentrics, causes the valves to move simultaneously. Many arrangements have been made and carried out to meet these requirements. In some cases the shifting rod is connected to a lever, the latter being keyed on a weigh shaft, to which motion is imparted by a worm and toothed quadrant. In other instances, a pinion and wheel have been preferred; while a third example omits the wheel, and the rod is connected to a shifting rack, the latter being worked by the pinion. Each arrangement, it is noticed, accomplishes the same result, although the mechanical contrivances are different from each other.

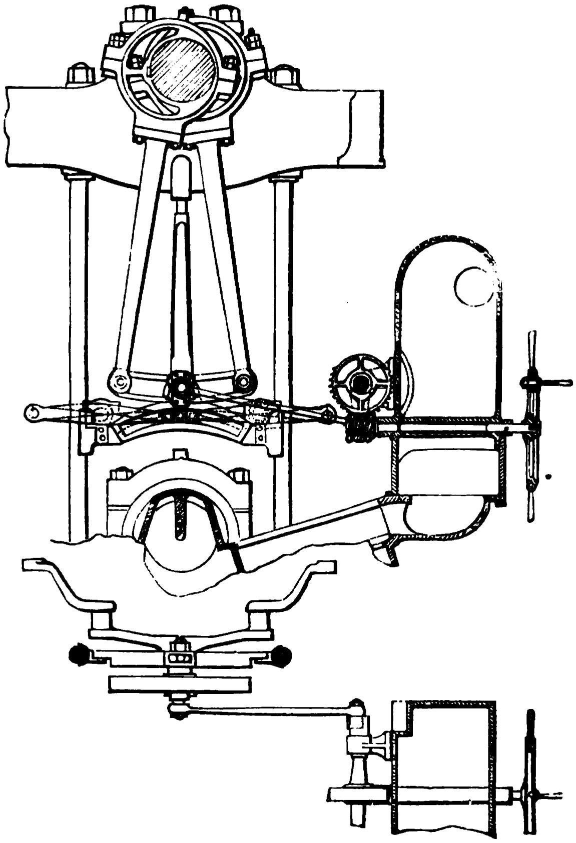
With the example on the preceding page, the arrangement of the starting gear is unlike any other just alluded to; for, the principle of the motion is a direct action, this being attained by a revolving screw and sliding cross-bar. The side elevation shows the screw supported in a frame at each end, with the starting wheel beyond the outer bearing. The cross-bar is also shown, but more clearly in the plan of the gear. The connection with the links is attained by flat rods hung at each end of the bar. In order to counteract the spiral action of the screw, and preserve a direct motion for the bar, two side guides are used, and a central slipper guide directly under the screw. It will thus be understood that, on imparting a rotatory motion to the screw by the hand-wheel, the cross-bar receives the effect, and a sliding motion is imparted, by which means the link is shifted in the desired direction. The end elevation represents the position of the wheel between the cylinders, and its height from the trunnion centres. The principle of this arrangement is used by many firms besides Messrs. Watt: for example, Messrs. Penn, Maudslay, Ravenhill, Napier, and Hawthorn have constructed and applied it for "screw" engines.

The shifting of the link, as before noticed, can be accomplished by various arrangements of the details. That just alluded to is a direct action, or a sliding motion for the actuating ends of the connecting rods. Now, while admitting that this is the correct motion, it must not be forgotten that complication for the working parts is introduced; and attendant also is the expense of manufacture and repair. To reduce those evils is the aim of all right-thinking engineers, and the firms in connection with the examples alluded to are not behind in this matter: inasmuch that they do all they can to reduce them.

For engines of small or moderate power, and where the slide valves are of light weight, and therefore easily moved, the arrangement illustrated by Fig. 69 is often preferred. This is an example of general practice by many eminent firms, one of them being the Messrs. Dudgeon, from whose working drawings those engraved were compiled and produced. This arrangement is termed the worm, wheel, and lever motion, of which the following is the description. The side elevation shows the eccentrics, link, sliding quadrant, and working levers at half-stroke; the entablature and trunnion-block being shown complete, beyond the gear. A portion only of the condenser is represented in section; but a complete sectional elevation of the discharge chamber is shown, to show the means for supporting the starting wheel shaft, which is a tube cast with the chamber, and a loose collar, secured, on the outside prevents any lateral movement. The hand-wheel is keyed on the shaft, and the horizontal projecting handle on the wheel is for the purpose of quick manipulation, when required. The shaft has formed with it, at the other extremity, a coarsely pitched screw, generally termed a worm. A toothed quadrant or wheel, gearing with the worm at right angles to the starting wheel, is keyed on a motion shaft, the latter being supported in brackets, secured to the side of the chamber. At the ends of this shaft, levers are keyed and connected to the links by rods, thus any motion given to the starting wheel is transmitted to the links, and from them to the slide valves, to start, stop, and reverse the engines.

The arrangement of the working-levers and quadrant, in relation to the starting wheel, is seen in the plan, one set of levers only being represented, which are supported by plummer-blocks—seen in the elevation only—secured to provisions formed on the cylinders. The dotted curve, seen in the elevation of the *chamber* near the quadrant, is explained by the plan: being the space requisite for the action of the working lever. The principle of this arrangement is so obvious from the illustration, that it is only necessary to state, that, on motion being imparted to the wheel, the worm acts on the toothed quadrant, and the levers,

FIG. 69.



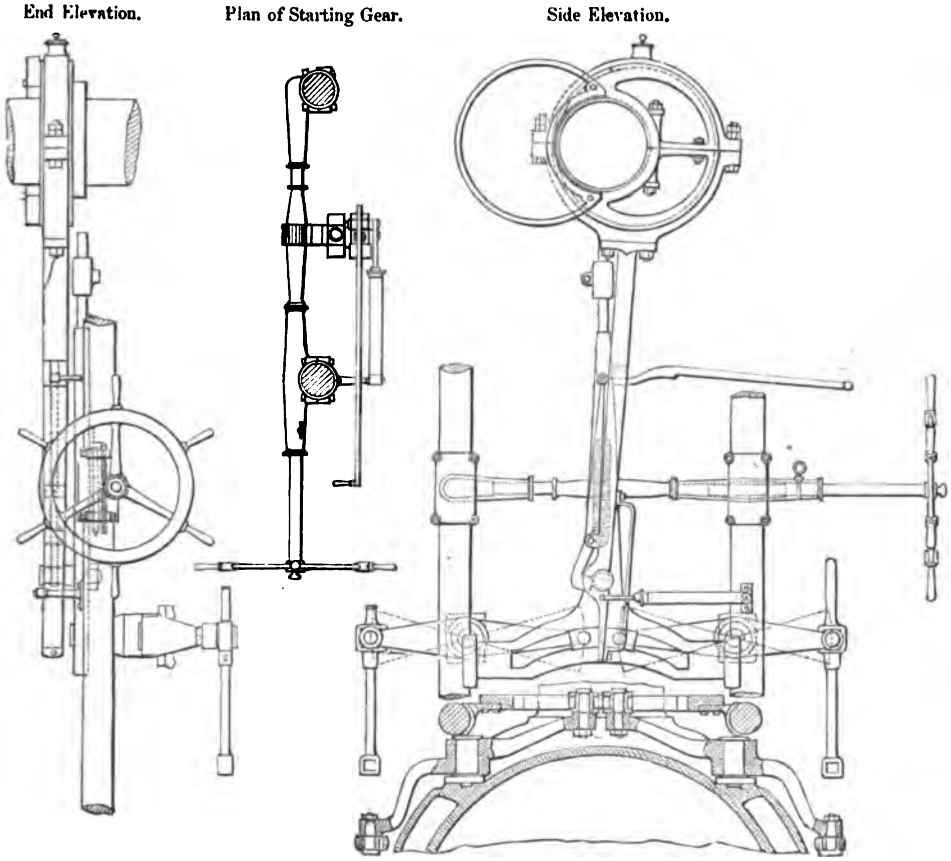
Messrs. Dudgeon's Link-Motion and Starting Gear for Oscillating Paddle-wheel Engines, as used by them and other firms, in the year 1862.

by their connection with the link, shift the same, and thus the slide valves, are raised and lowered as required.

To correctly understand any branch of science or arrangement of mechanism is first to become acquainted with the principles of the requirements: and by them the engineer should regulate all his productions: and obviously also whether one, two, or more attainments are required at once, each is alike in principle. The motion for the slide valve is a simple effect to be produced, but the main question is the best means for preventing that motion when such is desired. The link, when at half travel, brings the working levers on the horizontal line, and thus the slide valves cover the ports, but the speed of moving the valves entirely depends on the power expended to shift the links. Another fact also presents itself for notice, which is: that when the eccentrics are in a certain position the link *cannot* shift the valve to produce much effect, and thus one engine actually has to start the other. Now to obviate this, the entire *disconnection* of the slide valves from the eccentric motion is required, and thus the arrangement represented by Fig. 70 is often used by some authorities in preference to those examples having had prior notice. To fully appreciate this arrangement, the main effect must be remembered, viz., "independent means for working the slide valves." In this case the valves can be shifted to the full, or any portion of the stroke, irrespective of the angle of the eccentric or position of the steam piston, and thus the engine can be held—so to speak—without any regard to the mechanical means for working the valves. Now, to render this matter useful for practical purposes, the following description is given in connection with the drawing.

The side elevation represents the eccentric at half stroke, also the sliding quadrant and working levers. The eccentric has attached to it a portion termed a "counterbalance," the utility of which is that the eccentric—being loose on the shaft—retains a horizontal, vertical, or any equilibrium position as determined on, when the rod is disconnected from the sliding quadrant. For the purpose of fixing the eccentric at the requisite angle, for going ahead or astern, stop pins are inserted in the crank shaft, projecting beyond the periphery. Suitable projections in the boss of the eccentric bear against either pin when the rod is in gear; the direction of the rotative movement causing the constant contact of the pin and eccentric boss. On disconnecting the eccentric rod, the eccentric retains the equilibrium position—already alluded to—and remains stationary until the pin comes in contact with the projection by the rotation of the shaft, and then the engine works its valves.

Fig. 70.



The English universal Single Eccentric Motion and Starting Gear for Oscillating Paddle-wheel Engines, as used in the year 1862, and twenty years previously, by nearly all the leading Marine Engineering Firms.

Next, attention must be given to the starting gear. Presuming the engines are to be stopped, the hand lever—level with the top of the starting wheel—is pushed towards the eccentric rod, and the lower end of the lever being cranked into a slot in the rod forces the rod from its bearing on the quadrant pin. The pin then works in the loop secured to the front side of the rod, and the cranked end of the lever prevents the eccentric rod returning to its bearing. When the engines require to be started, the hand wheel is used as a preliminary means for working the slide valves. Now, assume that the eccentric rod is disengaged as described, the working of the slide valves is independent of the eccentric. The position of the starting wheel will be as that seen in the drawing under notice; or in gear; although the eccentric rod is shown connected, which is only for the means of representing the application of this gear. On referring to the end elevation, it will be noticed that on the starting wheel shaft a pinion is secured, and this gears into a rack, the latter being secured to the sliding quadrant. Now, on turning the pinion, the rack ascends or descends, as may be required, and thus a movement is imparted to the slide valves similar to that derived from the eccentric. The plan of the starting gear, between the elevations, conveys a ready understanding as to the connection of the several portions of the details, and the sectional plan of the working gear—under the side elevation—illustrates the form requisite for the levers and position of the quadrant, and means for guiding the same, together with portions of the cylinder and steam passages.

Having thus far become acquainted with the requisitions of this class of valve gear, and the mechanical means to maintain the same, a little attention devoted to the advantage of the arrangement will not be misapplied. Suppose a ship, fitted with oscillating paddle-wheel engines, and single eccentric motion and starting gear, as last shown, is required to be reversed in her movement as speedily as possible, the application of the gear in question will be thus apparent. The eccentric rod is thrown out of gear—as explained—and the starting pinion pushed in gear with the rack, the quadrant then imparts the required motion to the slide valves, to cause the steam to enter the cylinders at the opposite ends—the direction of turning the wheel of course determining this latter effect. On the engine starting, the eccentric rod can be set on the quadrant pin, as soon as the latter is level with the opening, and the spring—contained in the box connected to the entablature column—retains the rod in its bearing. The pinion, on the starting wheel shaft, being withdrawn from the rack on the quadrant, the eccentric becomes the agent for working the valves, without affecting the wheel.

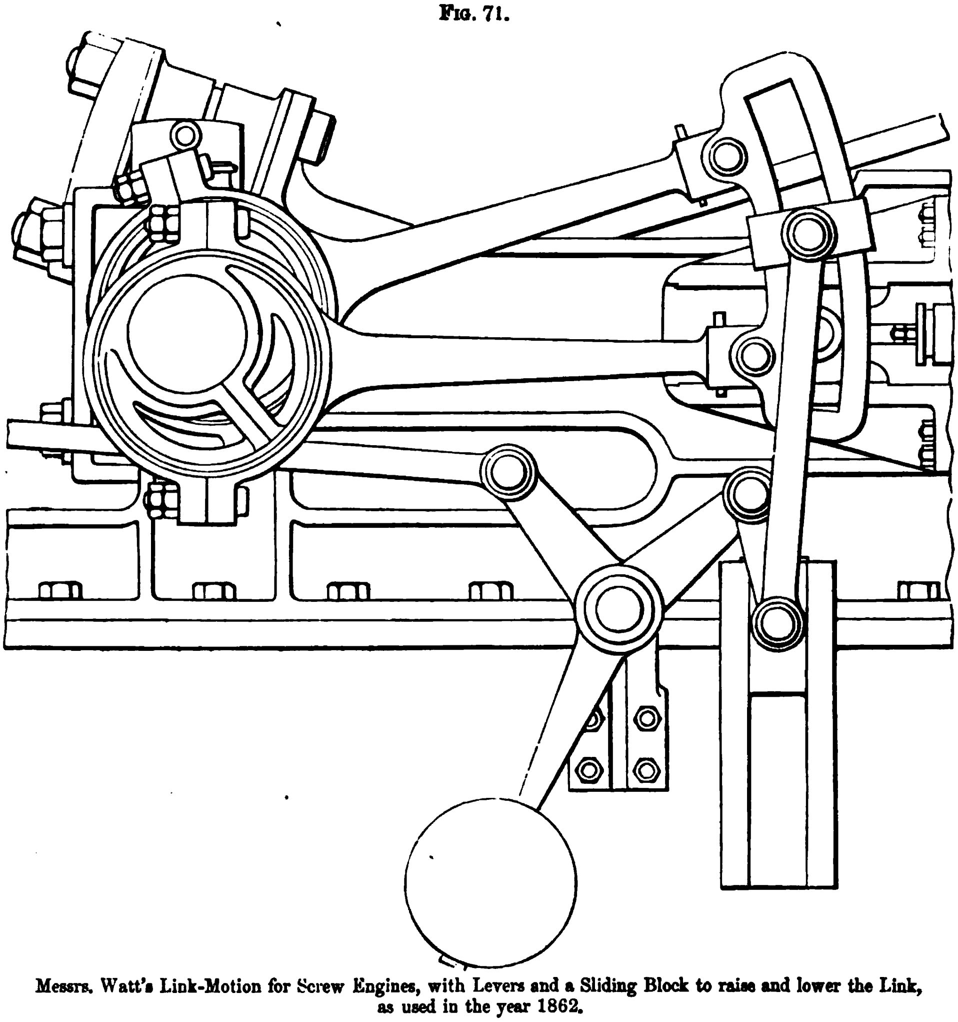
When the engines are required to be "brought up" suddenly, as in the event of a collision or any other cause, the disconnection already described occurs; and, on the starting pinion gearing with the rack, the slide valves can be instantly set at half-stroke, thus preventing any admission of steam into the cylinders, and also steam can then be admitted into their opposite ends by shifting the valves sufficiently.

The main advantage with this gear is, therefore, that the valves can be "handled" separately, at any portion of the stroke of the piston; and both pistons can be operated on by the steam equally if required, for the purpose. Obviously also, when the valves are worked by the motion of the eccentric, and disconnection is not permitted, the speed of the pistons determines that for the valves; but when hand, or separate power, shifts the valves, the admission or stoppage of the steam is more readily acquired. Large engines, fitted with the gear under notice, can be started, stopped, and reversed almost instantaneously, without over straining any portion of the gear.

It is preferred, in some instances, not to use the spring and box—for the purpose of holding the eccentric rod on the quadrant pin—but to use a lever with a catch-spring, connected to a slotted quadrant; the latter being secured to the side of the discharge chamber of the air pump—the starting wheel, in this case, being beyond the chamber. With this arrangement, the horizontal hand lever with the cranked end is dispensed with, also the slot in the eccentric rod, and the lever connecting rod is attached to the back of the loop instead of the side of the rod as in the example illustrated.

For engines of small or moderate power, or between ten to fifty horse-power nominal collectively, the hand wheel is not requisite, because the valves can be shifted by long double levers; the ends of the lesser lengths being connected to the quadrants. During the motion of the valves the starting levers are somewhat affected, which, for small engines,

FIG. 71.

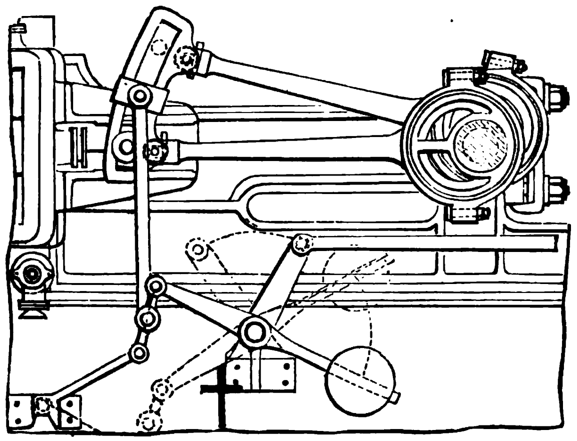


Messrs. Watt's Link-Motion for Screw Engines, with Levers and a Sliding Block to raise and lower the Link, as used in the year 1862.

is not of much importance; but the adoption of either the "wheel" or "lever" for manipulation depends on the power requisite to shift the slide valves; the less the friction, therefore, often due to the pressure of the steam; the less the power requisite to "start, stop, or reverse" the engines.

The firms at present most partial to the arrangement illustrated on page 85 are Messrs. J. Penn and Son, Messrs. Maudslay, Sons, and Field, and Messrs. Ravenhill and Hodgson. Each of those authorities differ slightly in their notions of design, but they of course accomplish the same result in the end. The example illustrated is very similar to the practice of Messrs. Penn and Messrs. Ravenhill.

FIG. 72.

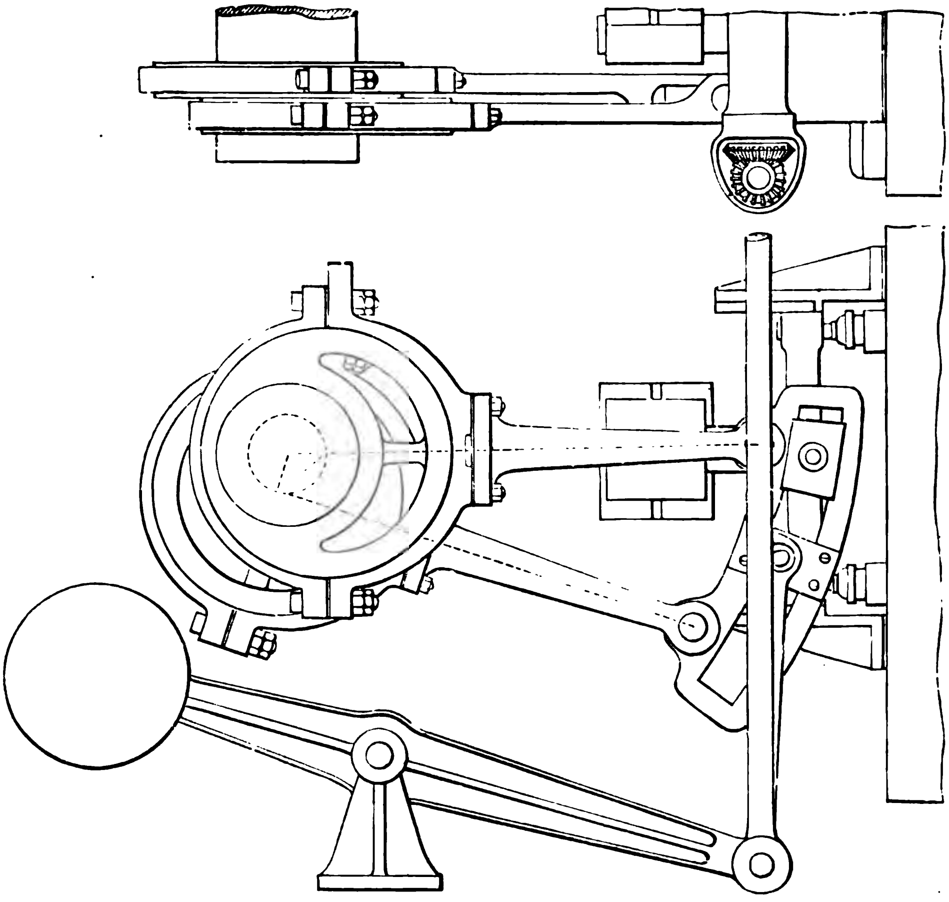


Messrs. Watt's Link-Motion for Screw Engines, with their Parallel Motion for raising and lowering the Link, as used in the year 1862.

We next explain and illustrate the best arrangements of link-motion for screw engines, as they are popularly termed, or engines applied for working screw-propellers, beginning with the arrangement by Messrs. James Watt and Co., as shown by Fig. 71; the main accomplishment of which is that the fixed end of the pin, on which the link suspension rod is secured, *always* rises and falls *vertically*, as its extremity works in the guide piece that is secured to the main frame for that purpose, and the reversing gear consists of levers and a counterbalance, worked in a similar manner, as shown by Fig. 68 on page 80.

Messrs. Watt have also another arrangement, to attain the same effect as that just referred to, which is illustrated by Fig. 72 on the preceding page. In this case their well-known parallel motion is brought into practice for the purpose, and performs the requirements equally as well as their sliding pin and guide arrangement, shown by Fig. 71.

FIG. 73.

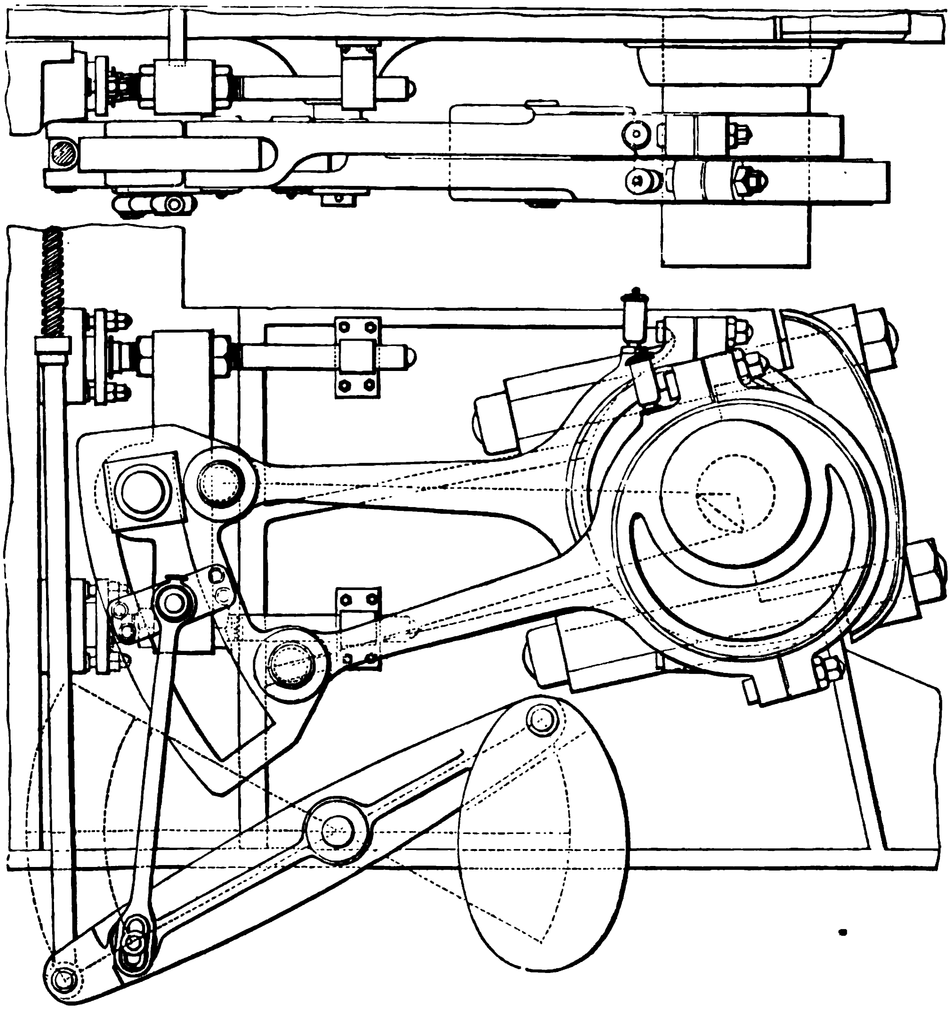


Messrs. Penn's Slotted Link-Motion for Screw Engines, with Screw-rod and Lever for raising and lowering the Link, as used in the year 1862.

We direct notice next to Messrs. John Penn and Son's arrangement of link-motion, as shown by Fig. 73. The link is the slotted kind, the eccentric rods being connected *within* the extremities, and the suspending point is at the *centre* of the link. The eccentrics are the usual type with gun-metal bands and wrought-iron rods. The link is raised and lowered by a screwed rod receiving motion from mitre gearing on it and the hand-wheel shaft. The weight of the link, pins, rods, and sliding block is counterbalanced by the lever and balance weight below the "motion;" and thus the power requisite for shifting the slide valve is greatly reduced. It will be noticed that two valve rods are adopted, and the requisite guidance is above, below, and central of the rods, by which positions a direct action is certain. When the firm in question use a single rod for the valve rod the central guide is adopted only: of a square section across.

To be noticed next, also, as an improved example, the illustration, Fig. 74 on the next page, is worthy of record. This is an arrangement by Messrs. Maudslay, showing their experience in the matter. It will be seen that the principle of the action is nearly as that of Messrs. Penn's arrangement, but the design varies in many points. The lifting rod is connected to the centre of the link, and the rod is looped at the connection with the lever, and thus the link *rests* on the sliding block. This is contrary to the connection in Fig. 73, where the rod is connected alike at each extremity, and the link *hangs* on the connecting pin. The position of the screwed rod in Fig. 74 is behind the link, and thus the lifting rod is in advance, or two separate connections with the "balance lever;" but Messrs. Penn, it will be seen, prefer a single connection, or at the extremity of their lever. With Fig. 74 the slide rods are guided by brackets secured to the main frame—the latter being shown in the plan and elevation. The central guide for the cross bar, as seen in Fig. 73, is omitted by Messrs. Maudslay, and the block pin is fixed behind the bar, rather than nearly centrally of its width, as adopted by Messrs. Penn. Messrs. Maudslay prefer the eccentric rod and half band to be in one forging, lined with gun metal where in working contact. The counterbalance is *hung on* the lever, rather than

FIG. 74.

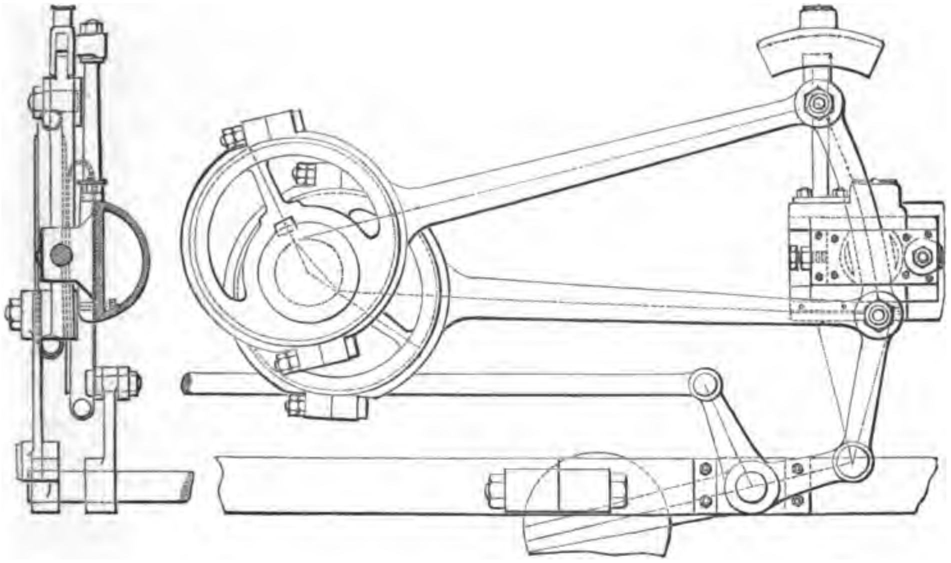


Messrs. Maudslay's Slotted Link-Motion for Screw Engines, with Screw-rod and Lever for raising and lowering the Link, as used in the year 1862.

fixed, and the weigh-shaft is supported in the main frame, thus dispensing with the bracket used by Messrs. Penn. Excepting these differences of opinion alluded to, both the firms have decided almost alike on the same subject.

Not long ago in the front rank of marine engineers stood the late Edward Humphrys, not only for his inventive faculties, but also for his practical treatment of any detail he investigated. The arrangement of the link-motion that he adopted was originally introduced by Mr. Nasmyth, but improved on and brought to its present state of perfection by Mr. Humphrys, as shown by Fig. 75. This arrangement consists of a *solid* bar as the link, instead of the slotted kind used by Messrs. Watt, Penn, and Maudslay. This link passes through the block, which is partially cylindrical, and the curved sides permit the oscillation required. The adjustment of the wearing surfaces is accomplished by the set stud on one side, and the slide valve rod at the other; the rod being screwed in its connection with the portion enclosing the blocks; the nut outside the plate preventing looseness of the connection. The

FIG. 75.



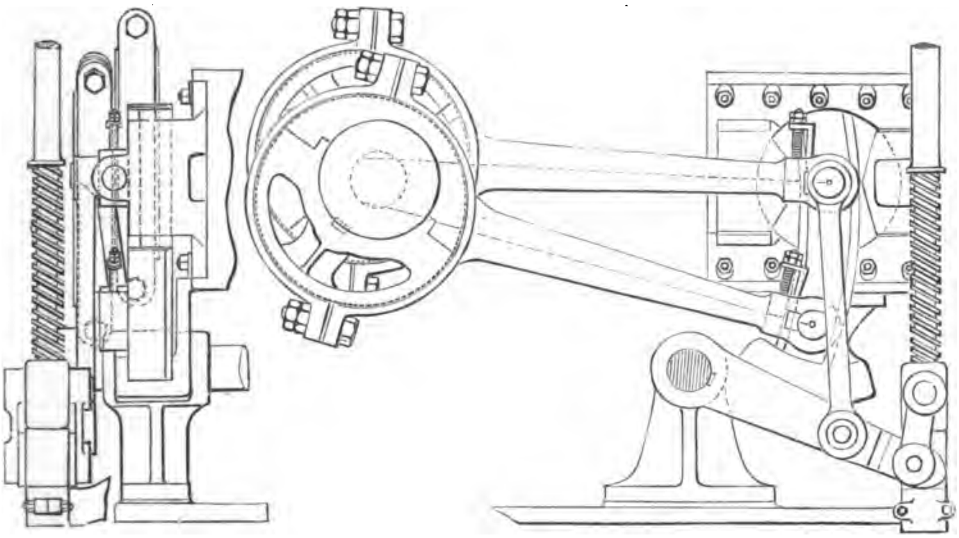
Messrs Humphrys' Solid Link-Motion for Screw Engines, with Lever Motion for raising and lowering the Link, as used in the year 1862; but was made and applied by Mr. Nasmyth to a Winding Engine in the year 1852.

sliding portion is guided in a flat dovetailed guide, which latter is a hollow bracket secured to the front of the casing; and the adjustment of the surfaces in working contact is ensured by bolts and nuts securing the adjustable or lap portions of the guide.

The guiding portions of the valve rod having been thus far explained, attention is next directed to the link and its connections. The eccentric rods are attached in the ordinary manner by being forked and clasping the link—bolts and nuts being used in the place of the usual pins and washers. The upper extremity of the link is prolonged beyond the rod's connection for the purpose of being guided when in the position shown. The guide is a curved slotted block supported on a standard or rod of wrought iron secured on the hollow bracket. The lower extremity is connected to the lifting rod, and the latter to the lever requisite to impart the required motion to shift the link; the other lever nearly vertical being in connection with the starting gear. The remainder of the details can be so well understood from the drawing, that further description is not requisite.

The firm to be referred to next, as constructors of "solid" link-motion, are Messrs. Ravenhill. Their arrangement will be understood by referring to the example illustrated by Fig. 76, together with the following description.—The link is dovetailed on one side, and passes through the block, which is in separate portions. The sliding piece supporting the block is dovetailed at the back, and fits in a guide bracket of corresponding form, the adjustment of the guiding surfaces being by studs and nuts securing the guide plates. The centre line of the eccentrics, in plan, is a continuation of that of the slide valve rod; but the connection of the rods is at the *side* of the link, rather than clasping the same, as in the previous examples. The pins are fitted with brasses, and their adjustment is effected by keys and screwed cotters fitted in the rods. The arrangement for raising and lowering the link is unlike any of the previous examples, although almost similar details are employed; in this instance the screwed portion of the rod is nearly opposite the link, instead of above or below it. The lever is connected by two short flat rods to the *sliding* block on the screwed rod; the lifting rod being connected to the upper eccentric rod's pin. Now, on revolving motion being imparted to the screwed rod by the overhead mitre gearing, the screw block will rise *on* the rod, and, by its connection with the lever, raise the link. It will be remembered that Messrs. Humphrys guide the *upper* extremity of the link. Now

FIG. 76.

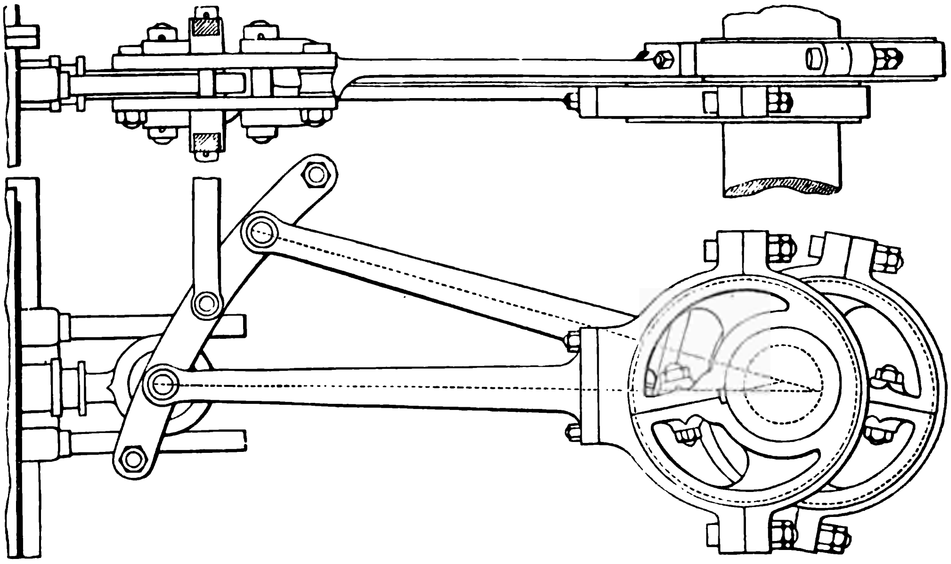


Messrs. Ravenhill's Solid Link-Motion for Screw Engines, with a Screw-Rod, Sliding-Block, and Lever for raising and lowering the Link, as used in the year 1862.

Messrs. Ravenhill, it will be seen, guide the *lower* end, by the bracket secured *below* the valve rod-guide bracket.

The arrangement of link-motion next to be noticed was originated by Mr. Howe, and used by him in the year 1847, and has with equal success been applied by Messrs. Dudgeon, of London, in connection with the engines fitted in the M.S. "Ruahine." This example is illustrated by Fig. 77, on the next page, and the following description will render its advantages conclusive.—The link is in two separate portions connected at the extremities by bolts and nuts. The block is enclosed in the eye of the valve-rod, and is recessed on each side to receive the links, and by its being thus enclosed in the eye of the valve rod the support for the necessary vibration is simply attained. The upper and lower surfaces of the eye of the rod are guided by two rods above and below, that are keyed into bosses formed on the casing, and thus any deflection is obviated. The eccentric rods are attached to the *outer* surfaces of the links, separate pins being requisite for each connection. The suspending or lifting rods are connected centrally of the link, and thus an uniform action is certain, irrespective of the direction of the crank's movement. With this arrangement there are certain advantages worthy of comment; the centres of the block and eccentric rod's pin are on the same point, also the link is suspended centrally of its length, and strength of material is gained by its peculiar form and mode of connection.

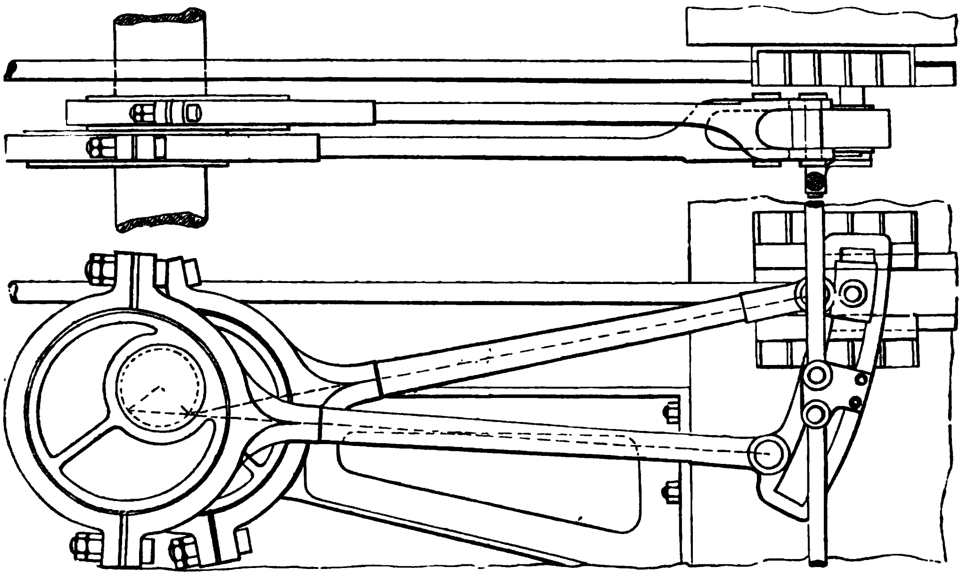
FIG. 77.



Messrs. Dudgeon's Twin "Solid" Link-Motion for Screw Engines, with a Central Connection for raising and lowering the Link, as used in the year 1862; but was invented and applied by Mr. Howe (the inventor of the link motion) in the year 1847, to a winding engine now working.

It will be remembered that with all the previous examples alluded to, the link is directly in front of the valve casing, or on the same side of the crank shaft as the cylinders. This situation is, however, by no means compulsory, for Messrs. Napier and Rennie have often fixed the valve rod-guide and suspended the link to and at the side of the condenser; the slide valve rod being prolonged to connect with the sliding piece supporting the block pin, and thus a return action results. This arrangement will be better understood by looking at Fig. 78. The valve rod, it is seen, is above the crank shaft—the Messrs. Rennie prefer two rods above and below the shaft—and inside the eccentric rods; the guide-block is a flat plate, bevelled at the edges, working between corresponding guide pieces secured to the side of the condenser. The link is the slotted kind, hung at the centre of its length, by the end of the upper lifting rod, the other extremity of which is attached to a sliding-screw block above the link. The lower rod is connected to a

FIG. 78.

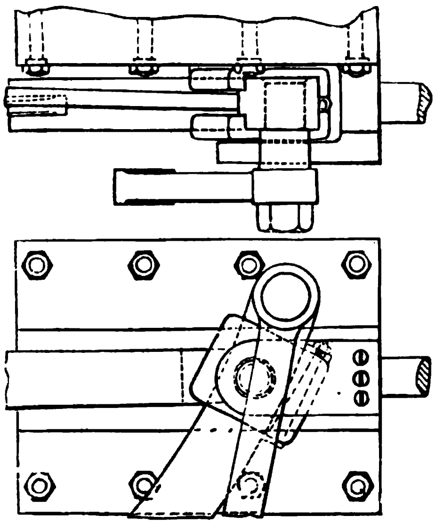


Messrs. Napier's Slotted Link-Motion situated opposite to the Cylinders, for Screw Engines, with the Slide Valve Rod *above* the Crank Shaft, as used in the year 1862.

lever below, the shaft of which is in connection with the counter-balances and steam starting gear. This arrangement for the situation of the link is particularly adapted for return-action engines, where the position of the cylinders is as close to the cranks as the half stroke of piston and clearance for the connecting rod head will permit. It is also certain in its application when *long* eccentric rods are required.

The connection of the valve rod with the link is an important matter in the arrangement of link-motion, and it will be observed that only Messrs. Humphrys and Dudgeon adopt a central connection in plan for the link and slide valve rod. By Fig. 79 a mode of connecting the solid link and the valve rod is represented, as adopted by the author; the block encloses the link, and has projections on each side for support, each of which are inserted in the forked portion of the valve rod. The block is open at the front to allow the centre of the eccentric rod to be on the centre of the block both in elevation and plan. The adjustment of the wearing surfaces of the block is effected by a back plate and key; the front surfaces being steeled to cause equal wear at those parts. The link is slotted at the extremities to receive the rods, but solid between; thus a single-eye eccentric rod is available, combined with a single solid link and a central connection.

Fig. 79.

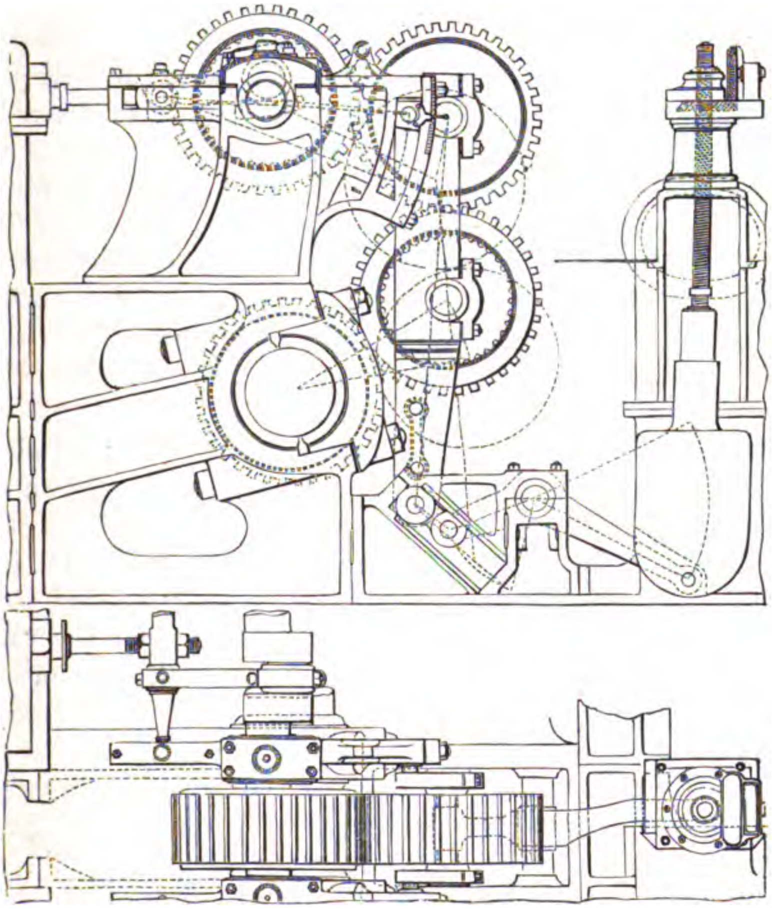


Burgh's Solid Link-Motion for Screw Engines, with a direct connection for the Eccentric Rod in a line with the centre of the Valve Rod, in plan and elevation, as used in the year 1862.

Common to all engineers is the fact that the cause for raising and lowering the link is to alter the position of the slide valve; now to reverse the principle of this, Mr. C. Sells has patented an arrangement of valve-gear adopted by Messrs. Maudslay, which is represented by

Fig. 80. The elevation shows four spur wheels in gear; two of which are fixed and the remainder loose on their shafts. The link is a *fixed* curve formed with each bracket supporting the valve cranked shaft; cranks being preferred in the place of eccentrics to impart the motion to the valves. The main, or first motion wheel is *fixed* on

Fig. 80.



Messrs. Maudslay's (Sell's patent) arrangement of Spur Gear and Stationary Link-Motion for three-cylinder Screw Engines, with Screw Rod and Mitre Gearing for reversing, as used in the year 1862.

the main crank shaft; the next wheel in gear and that directly above it are *loose* on their shafts, and the fourth wheel is *keyed* on the valve motion shaft. Now on motion being imparted by the first wheel to the second, the third and fourth wheels are respectively affected, and thus the constant motion for the valves is occasioned. To stop the engines the valves must be situated at half stroke, and this situation is occasioned by the block in the link being set at midway position. The attainment of this is, by the raising or lowering of the levers below;—the screwed rod and mitre gearing being the transmitters of motion from the hand wheel. It will be noticed that the two loose wheels are supported by the lifting rod, and the lower end of the rod is fixed to a sliding block fitted in the angular groove formed in the framing; the motions of the extremities of this rod are therefore curved at the upper end and straight at the lower. To start the engines, or rather shift the slide valves, the wheel on the valve shaft must be moved, while the lower wheel remains in gear with that on the main shaft. Now it is the constant contact of the teeth that effects this; for obviously when the main shaft-wheel is stationary, any motion given to the wheel in gear with it must cause the same to revolve, and thus the two wheels above are likewise turned around. The principle of the arrangement is therefore that the lower loose wheel is the "starting, stopping, or reversing" agent, and the wheel on the crank shaft the "driver." The arrangement of the details in plan is compact, and situated centrally of the engines in most cases, rather than as the ordinary link-motion, fore and aft of the outside cranks and frames.

Having fully investigated the link-motion as applied in the year 1862, and also as used for some time after, even to the present date, we will next explain the expansion valves and gear, adopted by the marine engineers before and after that period.

The side-lever engine had had full swing as the most popular and universal of all engines as far back as the year 1830, and we have no hesitation in stating, that for slow speeds and with ample engine room, that engine has even now no equal; for as the wearing and moving parts are perfectly balanced, the vibration is the least possible, and the repair, therefore, similarly reduced.

The valve gear in use with these engines was the single eccentric and rod, the former being loose on the crank shaft, with two pins in it for the eccentric to fix against, at opposite angles as required, for the forward or backward motion of the engines, as explained and illustrated on page 85, for oscillating engines.

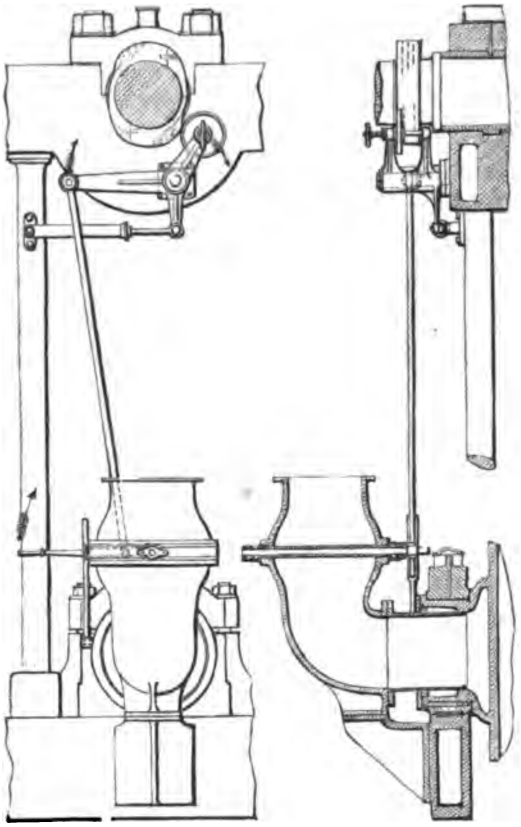
The expansion gear used was the "cam and roller" gear, which consisted of a series of cams in one casting, laid as it were one on the other at respective angles for separate purposes; and the roller was hung on a spindle, so that the roller could be regulated in position to gear with the cams, for the several grades of expansion that were provided for. This gear was used for oscillating engines also: on account of the slow speed those engines always work at comparatively with the direct-acting screw engines.

The illustration shown by Fig. 81, on the next page, is a very good example of cam-expansion-gear, as used even in the present day, but has been in general practice since the year 1840. It is represented in side and end elevations.

The side elevation shows the cams, levers, and motion at half-stroke—the steam pipe and valve casing being in front of the lever, and the trunnion plummer-block at the back. The end elevation represents the casing, valve, pipe, trunnion-block, and portions of the cylinder and lower frame in section. The expansion gear is shown complete, also the cam, but the entablature is shown half in section, and in complete elevation in the side view.

The action of the gear will be thus understood. The arrangement, seen in the side elevation, is a series of cams of unequal forms or curves: which are for the alteration of the grade of expansion when requisite. The motion of these cams is imparted to the throttle valve by a series of levers. These levers are cast together with one boss, thus forming a "carriage," the shaft of which is secured to the entablature. The perpendicular lever connected to the spring-box, is always pushing towards the opposite column, and thus the roller, that is hung on the pin of the angular lever, is when in gear pressing on the cam ; therefore the cam, when revolving, causes the horizontal lever to rise and fall. The connection of this lever with that on the throttle valve spindle, is by a single connecting rod. At the side of the casing is seen a perpendicular rod in connection with the handle lever, on the horizontal line. This lever works in a slot in this rod, and, with the use of a set screw, any position or angle for the valve can be retained. Should

FIG. 81.



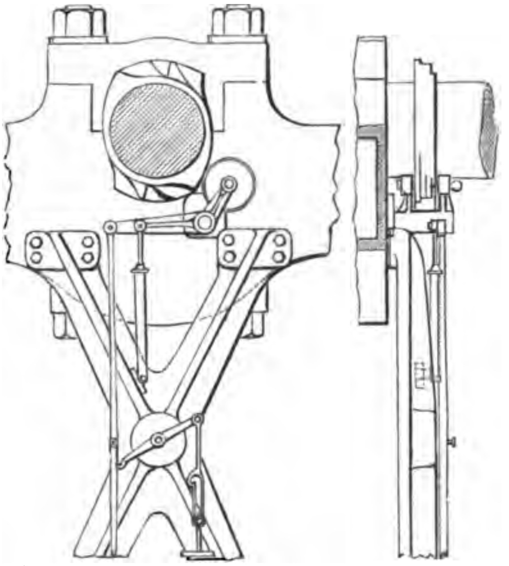
Ordinary Expansion Gear and Throttle-Valve for Oscillating Paddle-wheel Engines, as used by the leading Marine Firms in the year 1862, and for thirty-five years previously for Side Lever Engines.

the cam be required to revolve without affecting the valve, the roller can be thrown out of gear by the handle, and the whole of the levers will be held in the direction indicated by the arrows; the set screw rendering their position stationary. When the grade of expansion is required to be altered, the hand-pin,—on which the roller is hung, seen in front of the cam in the sectional elevation,—is turned to shift the position of the roller opposite to the required cam. The spindle is screwed in the present example, and a set-nut outside the boss retains the required position.

When "cross frames" are used as well as, or in the place of columns, the gear is arranged as shown by Fig. 82, which is the side and end elevations of the gear and its connections, minus the throttle valve and levers below, as shown in the previous example.

These two arrangements are very popular both in England and Scotland with the leading marine firms.

FIG. 82.

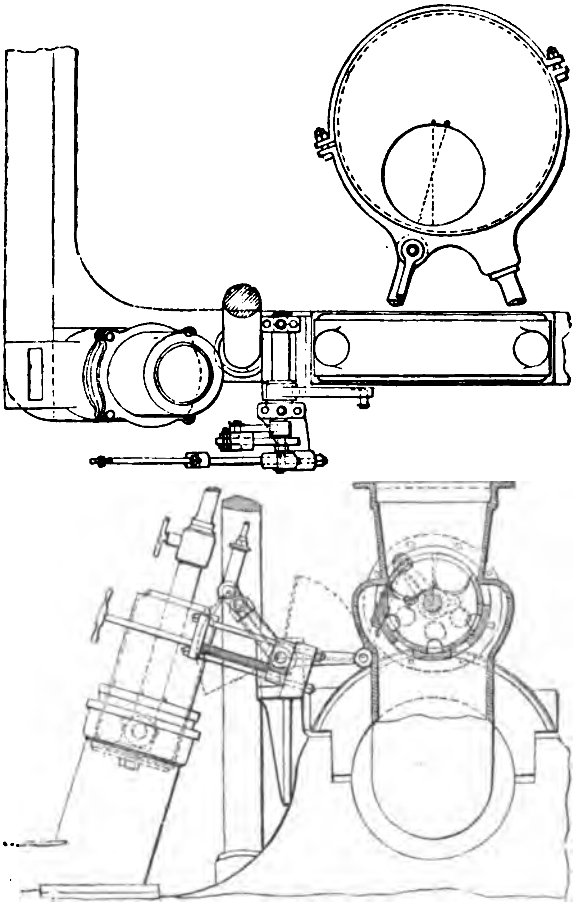


Ordinary Expansion-Gear for Oscillating Paddle-wheel Engines, as used by the leading Marine Firms in the year 1862, and for thirty-five years previously for Side Lever Engines.

The next example which deserves attention as a simple and effective arrangement, is that generally adopted by Messrs. Maudslay, Sons, and Field; this firm prefer the form and arrangement of the details as illustrated by Fig. 83, on the next page. The side elevation shows the valve and casing in section, and the gear complete behind the casing—the relative position of the gear will be better understood by referring to the plan. The eccentric, shown in elevation above the plan, is of the ordinary kind with a hoop or band, having three rods connected to its lower side. One rod, it is seen, is connected to the gear under notice and the remaining two to the feed and bilge pumps plungers—one pump being only shown in the elevation and plan of the arrangement.

The valve is cylindrical, with openings for the admission and regulation of the flow of the steam. The passage or opening in the upper side of the valve admits the steam, and the four openings below permit its escape to the passages in the casing. The openings in the inner

FIG. 83.



Messrs. Maudslay's Expansion-Gear and Vibrating-Valve for Oscillating Paddle-wheel Engines, as used in the year 1862, and twenty years previously.

shell of the casing correspond with those in the valve, and the widths of the solid portions of the latter determine the laps required. After the steam has passed through the valve, it flows into the passage in the casing, and from thence into the trunnion opening; the valve and casing being of such a simple character, that the sectional view only is deemed requisite to illustrate them.

The motion required for the valve is obviously vibratory, to admit and intercept the steam, which is attained by the rotary motion of the eccentric. The connection of the latter to the valve spindle is by a series of levers, with separate shafts and connections. The motion from the eccentric is transmitted in the following manner.—The rod attached to the eccentric band is connected to the first motion lever—shown at an angle—a second lever being shown on the horizontal line. This last—or second—lever transmits its action to a third but shorter lever, which is keyed on the valve spindle; the connection with this lever being attained by an adjustable rod.

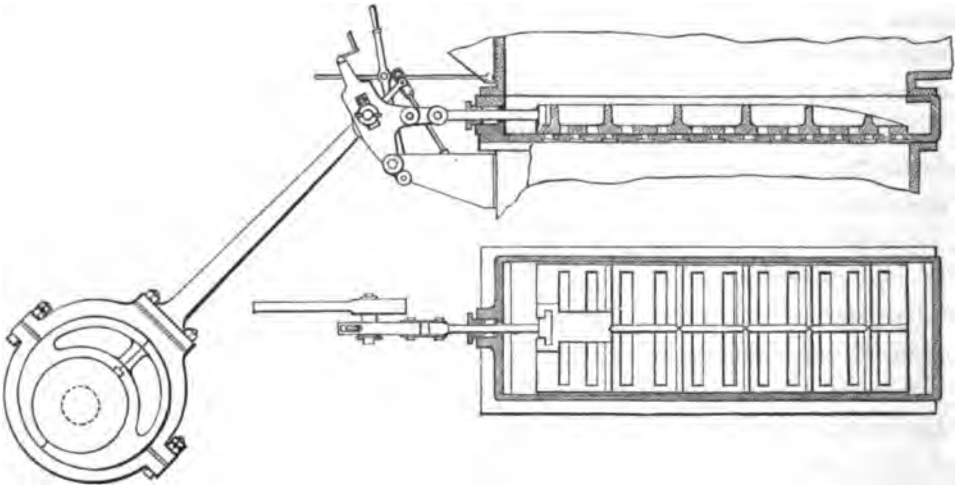
On alluding to the plan, it will be seen that the "first lever"—seen in the elevation as one—is actually two levers at the same angle. The front portion is secured on a pin, and the back part separately secured on a shaft, supported by a bracket cast with the trunnion plummer block. Inside the first bearing is the "second lever"—horizontal—in the elevation.

Obviously, from this connection, on the eccentric causing the first lever to descend, the second lever will ascend, and the third lever and valve will oscillate, due to their position on the spindle.

Thus far the motion is rendered apparent; further attention is now requisite to understand the mode of regulating the grades of expansion, to which the remaining portion of the gear—not yet alluded to—pertains. Forming a portion of the bracket alluded to, is a projection for the purpose of supporting two guide rods, angularly situated, and sustained at the extremities by a cap and nuts. Clasping the rods, at the back end, is an adjusting block, the motion for which is acquired by a third rod screwed between its bearings, and prolonged beyond the cap with a cross-handle. The two levers before alluded to, termed together the "first motion lever," are attached together by a dove-tailed portion at the extremity of the inside lever, the latter, by its connection with the shaft, remaining laterally fixed, while the former slides in common with the action of the block.

The dotted angular lines and arcs denote the travel of each lever, when the block is in the position illustrated. Now, on lengthening the "first lever"—by shifting the block—the travel due to the eccentric being unalterable, the motion of the "second lever" will be lessened in proportion to the difference in the radii described by the levers—both being shown as equal in the illustration.

FIG. 84.



Messrs. Penn's Expansion-Gear and "Gridiron" Sliding-Valve for Screw Engines, as used in the year 1862.

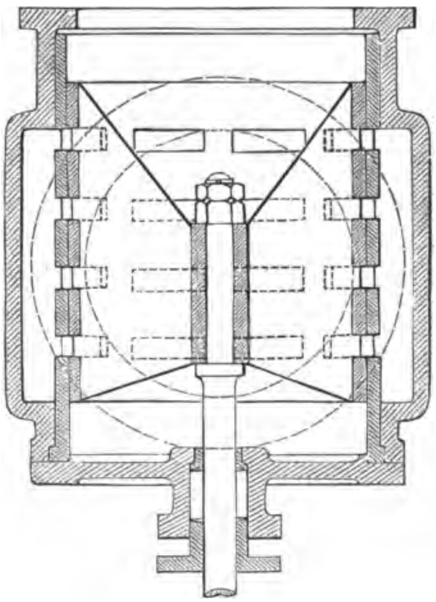
Further, if the motion or travel of the second lever is reduced by lengthening the first lever, obviously the travel of the third or valve lever will be affected proportionately. It will be noticed, also, that the shifting of the adjusting block not only lengthens the first lever referred to, but it also shifts the valve on its axis, and thus the grade of expansion is thereby altered.

Having done justice to the examples of expansion-gear for oscillating paddle-wheel engines, we will now refer to the best example for direct-acting screw engines, commencing with Messrs. Penn's arrangement, as shown by Fig. 84, on the preceding page. The expansion valve is the "gridiron" type, sliding on a seating of corresponding form; both being shown in side section and plan, further allusion is scarcely requisite. With reference to the "gear," it consists of an eccentric as a prime mover, and the rod is in connection with a slotted lever and sliding-block at the other extremity. The pin is fixed in the sliding block, that is contained in the grooved portion or link, supported by the bracket at the front of the casing. The cranked handle, above the projection over the groove, is fixed on the screw-rod passing through the block, thus the eccentric rod pin can be shifted in the groove when required, to suit the grade of expansion settled on. Suitable means for disengaging the rod and retaining it out of gear is ensured by the loop, guide rod, and hand lever shown above the bracket. The valve rod is connected by flat bars and pins to the link, and guides are obviated by the sufficient strength of the rod and shortness of the stroke.

Messrs. Watt, Napier, Humphrys, Ravenhill, Laird, and Maudslay now adopt, in most cases, the valve and gear nearly as those by Messrs. Penn, at least if not in design, the same in principle of effect and arrangement.

The firm next to be alluded to, who also adopt the principle of this arrangement, are the Messrs. Rennie; but in the place of a gridiron valve, a tubular, perforated valve is preferred, with a seating to correspond. This example is illustrated by Fig. 85, and

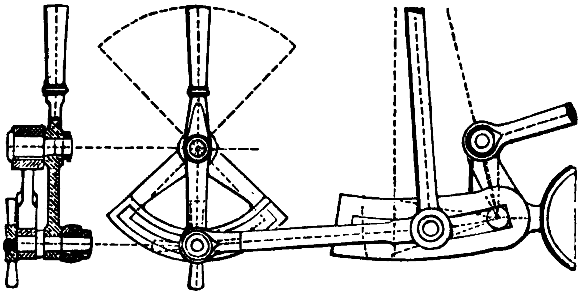
FIG. 85.



Messrs. Rennie's Sliding-Equilibrium Cylindrical Perforated Expansion Valve, Seating and Casing, for Screw Engines (similar to Atherton's, Fig. 29, page 32), used from the year 1853 to 1862.

shows that two tubes—one within the other—comprise the valve and seating, and the difference in the widths of the openings and solid portions between, produces the "cut-off" requisite. The valve slides up and down, and derives its motion from an ordinary eccentric, and the change of the grade of expansion is effected by a link and connecting rod attached to the valve rod. To understand the utility of these latter details readily, will be to refer to Fig. 86, which are elevations of the link, eccentric rod, adjusting handle and quadrant. The connecting rod is also shown at half stroke situated centrally of the slot in the link—the dotted lines on the quadrant depicting the utmost movement effective or neutral, as required. The lever, projecting above the link, is keyed on a portion formed with the link, and the counterbalance obviates the weight of the valve and details affecting the motion. The quadrant and hand lever are shown in section, to show the mode of setting the connecting rod, when the engine is in motion, if requisite. Obviously, the main advantage with the valve in question is, that the pressure of the steam *cannot* affect the surfaces in working contact, and thus an equilibrium action results.

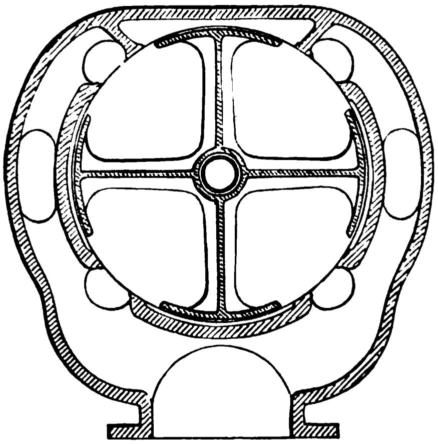
FIG. 86.



Messrs. Rennie's Expansion-Valve Link-Motion worked by an Eccentric, for the form of Valve shown by Fig. 85.

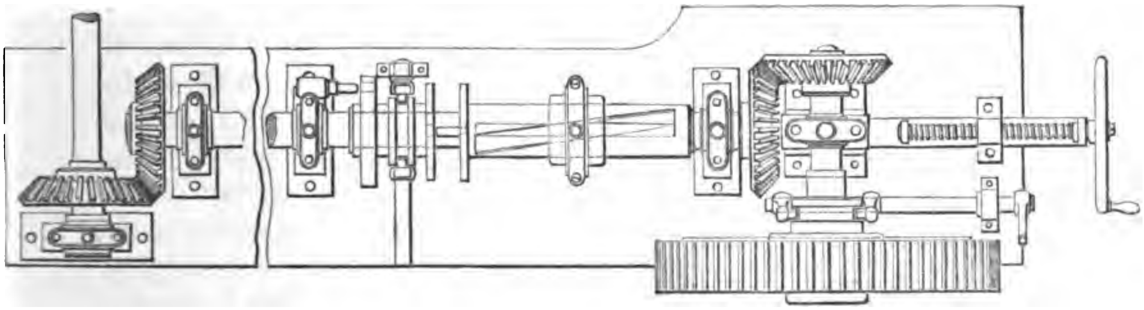
The "tubular valve" does not always receive a "sliding" motion, as the example by Messrs. Maudslay illustrates, as represented by Fig. 87. It is preferred by that firm to cause the valve to *revolve* within a barrel having openings or ports of *less* width than those in the valve, by which difference a variable cut-off is effected. The required motion is derived from the engine shaft, and transmitted to the valve by spur, mitre, and bevel gearing. One of the spur wheels, and the entire set of mitre gearing is illustrated in plan by Fig. 88. It will be seen that the counter shaft has fitted on it, between the bearings, a clutch coupling, with discs on each side of the clutch; one of the discs, when in gear with the *fixed* pin, holds the valve stationary; and the other, when coupled with that opposite, shifts the valve. As the latter attainment causes the grade or cut-off, it will be requisite to further explain the same. On the counter shaft, between the bearing and the coupling, is a *curved* grooved barrel, encompassed by a loose ring or boss fitted with a pin, which passes through the slot in the barrel and fits in a *straight* groove in the shaft. On the right hand of the mitre gearing is seen a hand wheel and screw, which latter is con-

FIG. 87.



Messrs. Maudslay's Cylindrical Revolving-Expansion-Valve, Seating, and Casing, for Screw Engines, used from the year 1840 to 1862.

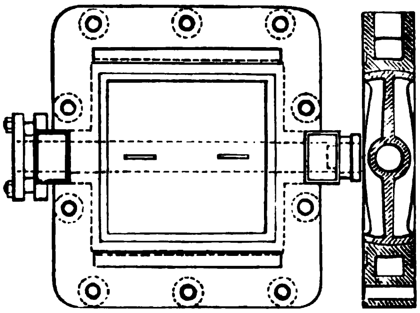
FIG. 88.



Messrs. Maudslay's Expansion Valve Gear for the Valve as shown by Fig. 87.

nected to the sliding boss on the barrel. Obviously, then, on motion being imparted to the hand wheel, the boss will advance and recede, and the barrel will be turned in a corresponding direction. It is almost needless to add that the *pitch* of the curve of the groove in the barrel is the main consideration in proportion to the *laps* of the valve to produce the several grades of expansion.

Fig. 89.



Messrs. Ravenhill's Expansion, Revolving-Flat-Valve for Screw Engines, as used in the year 1862.

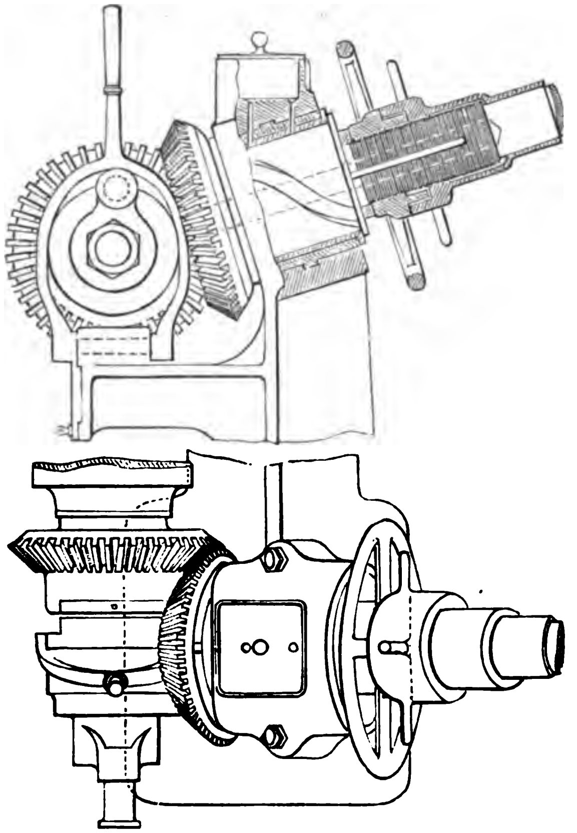
Messrs. Ravenhill have also adopted mitre gearing for expansion gear, but the valve, instead of being tubular, is square, with curved flanges—the width being proportioned to the stroke of the piston, speed of the valve, and grades of expansion. The casing encloses the valve, and the rod passes through both details, as illustrated by Fig. 89.

The arrangement of the gearing is simply accomplished as follows:—on the extremity of the crank shaft is secured a mitre wheel, a counter shaft—with a wheel at each end—imparts motion to a mitre wheel on the valve spindle;—a plan and elevation of the gearing is depicted by Fig. 90. The alteration of the grade of expansion is effected by a *grooved* barrel, situated directly behind the mitre wheel on the angular counter shaft. A hand wheel is used to turn the shaft, and a lock nut retains the required position for the valve. This arrangement will be more readily understood by alluding to the sectional view of the same—shown in the elevation. The mitre gearing is disconnected by the clutch and coupling on the extremity of the crank shaft, and thus the setting of the valve is effected without stopping the engines. The small crank in front of the coupling is for the purpose of working the hand pump when required.

It will be remembered, that in all the previous examples the alteration of the grade of expansion is effected by *shifting* the valve.

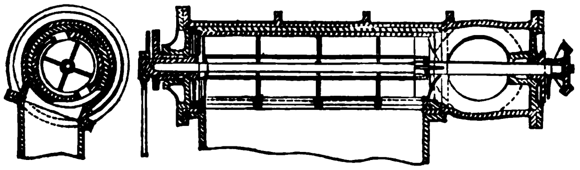
Now Messrs. Watt accomplish a similar result by shifting the *seating* on its axis, the valve being the tubular kind, as shown by Fig. 91.

FIG. 90.



Messrs. Ravenhill's Expansion Gear for the Valve shown by Fig. 89.

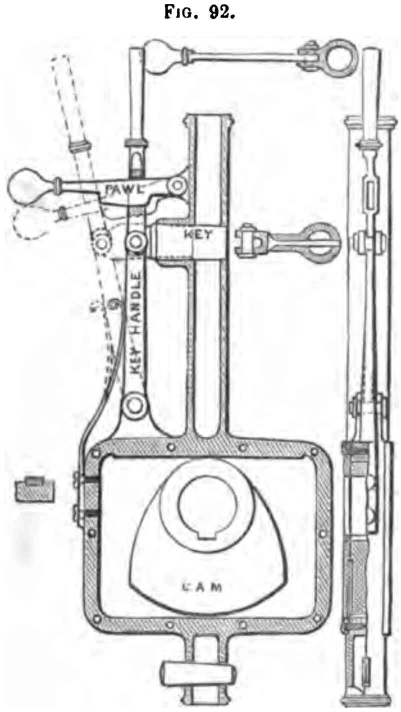
FIG. 91.



Messrs. Watt's Stationary-Equilibrium Expansion Valve, with a *Revolving Seating*: for Screw Engines, used in the year 1862, and thirty years previously.

The valve has two ports nearly opposite each other, but the openings in the seating are divided by narrow bars. The seating is supported within the casing, and the valve by the spindle in the centre. The bush that passes through the stuffing-box is connected to the seating by an internal coupling at the extremity of the same; and by the handle on the bush, the seating can be shifted around in the required direction to alter or set the grade of expansion. The motion for the valve being rotary, mitre wheels with the requisite counter shaft are used—one of the mitre wheels being shown at the extremity of the valve's spindle; those for the shaft being omitted.

FIG. 92.



Burgh's Rotary-Cam and Vertical-Motion Casing combined with Disengaging Gear, for Working, Supply, and Exhaust Steam, Equilibrium Cylindrical Valves of Beam Engines, applied in the year 1862.

Our remarks next refer to the valves and gear for land beam-engines, such as were used about the year 1862, for "winding, pumping, and blowing," and other requirements. For engines of small size, whether condensing or non-condensing, the ordinary eccentric motion and slide valve were used, as is indeed often at present; but for large engines, particularly for pumping, without the fly-wheel, the old Cornish valve-gear, as illustrated by Fig. 4, on page 10, was still adopted, and is used now with detailed improvements according to the fancy of the designer.

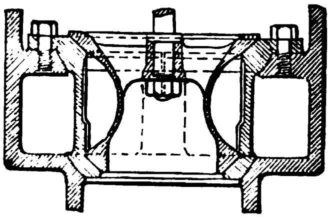
The strokes of the pistons of those engines are comparatively long, and their motion is similarly slow; therefore the cam-motion is applicable with every advantage, and for that reason the rotary cam, worked by mitre gearing from the crank shaft, has been universally adopted by the respective makers of beam engines. Amongst the general rotary cam motions, that arranged by ourselves may be referred to, as illustrated by Fig. 92.

The cam revolves with a shaft driven by mitre gearing, and the casing is a gun-metal box as deep as the cam is long and as wide as twice the radius of the end or main curve of the cam. The exhaust valve rod is keyed in the socket below the box, and the supply valve rod is loose in the long socket above the box when out of gear, and when in gear for working the engines, the disengaging key is inserted through it, as shown in full lines; the dotted position representing the key out of gear or for stopping the engine.

By this simple arrangement for disengaging the supply valve from the motion of the cam, engines of the largest power can be handled with one hand; because the little pawl when down keeps the key out of gear, and on lifting the pawl the spring in front of the key-handle drives it in; and an ordinary marine starting wheel, with suitable handles, on the cam shaft turns the cam separately when required, so as to start the engine exceptional to the mitre gearing, and similarly to reverse or stop it also.

The steam valve, seating, and part of the nozzle casing are shown in section by Fig. 93. The valve is scarcely equilibrium, as the top seating is a little larger than the lower, and a spring was used to counteract the unequal action of the steam on the two areas. The steam passed through the body of the valve before it entered the cylinder, and thus the valve readily closed when required. One cam was used to work each supply and exhaust valve for the opposite ends of the cylinder, by which arrangement those valves were side by side—top and bottom.

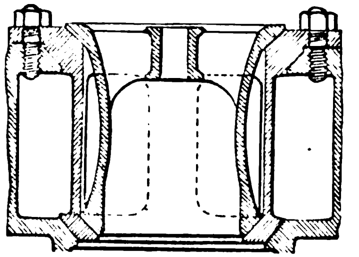
FIG. 93.



Burgh's ordinary Cylindrical double-seat Steam Valve and Seating for Beam Engines, applied in the year 1862.

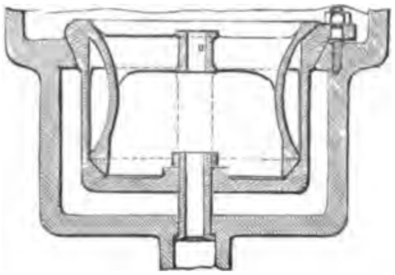
In another instance we used the supply valve as shown by Fig. 94, on the next page, but the steam surrounded the valve in this case between the seatings before it opened, and therefore by its shape also a more equilibrium action was permitted. The exhaust valve is illustrated by Fig. 95. The bottom of the seating is closed, and the steam passes through the valve before it is opened. With this engine the supply and exhaust valves were over each other, top and bottom of the cylinder, instead of right and left as previously described.

Fig. 94.



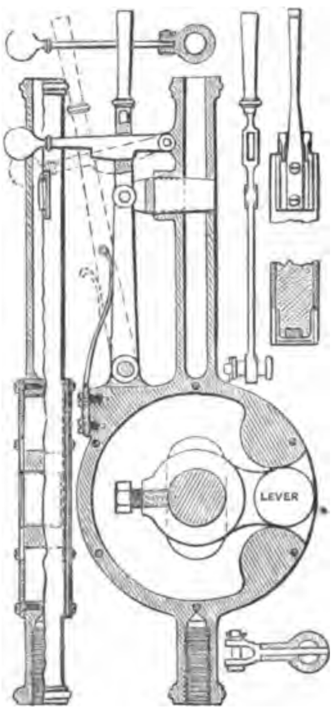
Burgh's nearly Equilibrium Cylindrical double-seat Supply Steam Valve and Seating for Beam Engines, applied in the year 1863.

Fig. 95.



Burgh's Equilibrium Cylindrical double-seat Exhaust Steam Valve, and Closed Bottom Casing, for Beam Engines, applied in the year 1863.

Fig. 96.

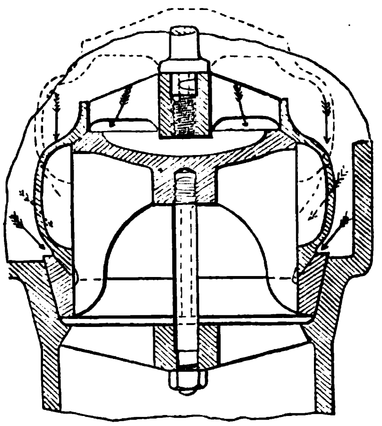


Burgh's Lever and Box Motion, with disengaging Gear for working the Valves of Beam Engines, applied in the year 1863.

The gear that we designed and used for these last two valves was mitre gearing, which from the crank shaft transmitted motion to a cam shaft and frame, guided by two standards; but as this was a winding engine and required to be reversed instantly, as well as stopped or started, we worked the valves by a lever and box motion, as shown by Fig. 96, the box being formed for symmetry more than for actual requirement. The disengaging gear is the same as that illustrated by Fig. 92 on page 112.

The original ordinary equilibrium steam valve for beam engines is shown by Fig. 97. In this case the relative positions of the smaller and larger seats are reversed to those previously illustrated, but the non-equilibrium action of the steam is the same in effect, because the relative diameters of the seatings are practically coincident. For example, in the previous valves the lower seat portion of the valve passes through the *inner* diameter of the upper seat; but in this case the lower seat portion of the valve surrounds or encloses the *outer* diameter of the upper seat, so that the unequal areas for the action of the steam is the same in both cases. As this valve is shown closed in full, and open by dotted lines, its utility can be readily understood without further description.

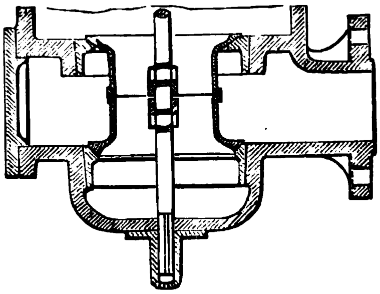
FIG. 97.



Original Cornish Equilibrium Cylindrical double-seat Steam Valve and Seating for Beam Engines.

In order to obviate the non-equilibrium action of those valves, we designed and applied the valves as shown by Fig. 98, which eradicated all the errors of the others, and proved to be of proportionate value as an attainment in practice. We made our new valves in halves of *equal* diameters, by which the seats were identical, and bolted the halves together centrally by nuts on the motion rod. By this arrangement we had a twofold advantage, which was, that the supply and exhaust valves could be made to close and open by the action of the steam, or *vice versâ*, while springs could be used, if preferable, to keep the cam box on to the cam face, if the seats of the valves were perfect duplicates, which of course in the other cases they were not.

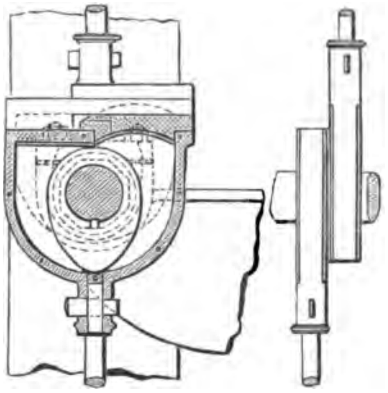
FIG. 98.



Burgh's perfectly Equilibrium Twin Seated Cylindrical Steam Valves for Beam Engines, designed and applied in the year 1865.

The valve gear we used was the unevenly-curved cams; the shaft on which they were keyed being driven by mitre gearing from the main crank shaft, and the cams were enclosed in a box or case of peculiar, but particular form, applicable for the grade of expansion, sudden cut-off, and release, with perfect exhaustion and ample lead. An illustration of this gear is shown by Fig. 99, so that it can be easily understood.

FIG. 99.



Burgh's Rotary Cam Motion with Expansion Curves for the Cam and Case, subject to the Lead, Cut-off, time for Expansion, the point of Release, and time for Exhaustion, applied in the year 1863.

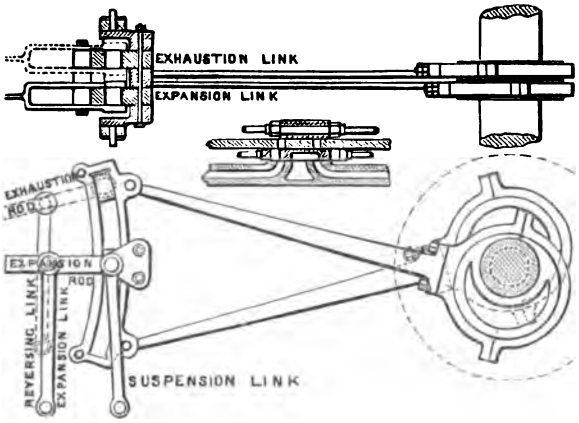
The exhaust and supply valves are side by side at the ends of the cylinder. The main advantage in this arrangement is that we could, and did, adjust and shape the cams—as they were separate for each valve—for any grade of cut-off, lead, or release, as we thought fit to experiment with, for the economical use of the steam in after practice.

At the beginning of the period we last referred to, Mr. J. F. Spencer brought out his new single-eccentric twin link-motion, which consisted of two distinct links placed side by side, and connected together so as to form double links to two eccentric rods worked by two eccentrics fixed on the crank or other shaft, so that one eccentric rod is attached to one end of the exhaustion link, and the other to the other end of the expansion link. The radius or connecting rod that is attached at one end to the exhaust valve, or its rod or lever, is attached at the other end to a sliding block in the respective link, and the radius or connecting rod that is attached at one end to the expansion or steam valve, or its rod or lever, is attached at the other end to a block sliding in its respective link. If the eccentrics are set as usual, one for forward and the other for backward gear, and the double link is suspended in one position, by moving the radius rod in the exhaust link, the exhaust valves can be reversed, and by moving the other radius rod in the expansion link, the steam valves can be reversed, and the expansion can be varied without in any way affecting the efficiency or action of the exhausting valves; or the exhaustion of the steam.

For stationary engines or engines that do not require to be reversed, two eccentrics with rods and only one single link are used, and the exhaust valve rod is connected to one end of the link only, while the steam or expansion-valve rod slides on the link to vary the cut-off.

The illustration, Fig. 100, is a side elevation and plan of the gear, with a section of the slide valves and cylinder ports and passages. The links for working the main and expansion valves are identical; the upper eccentric rod is for the back gear or motion; the lower rod is for the fore gear. Between the link and the valve rod the upper radius or connecting rod, as shown by dotted lines, is for the exhaust; whilst the lower or horizontally placed radius or connecting rod is for working the expansion valve. The double fixed link is held in position or supported by a vibrating rod, whilst the reversing is effected by a compound weigh shaft, formed by a tube surrounding a solid shaft. The positions of the reversing lever and expansion lever as operating upon their respective link blocks are also shown.

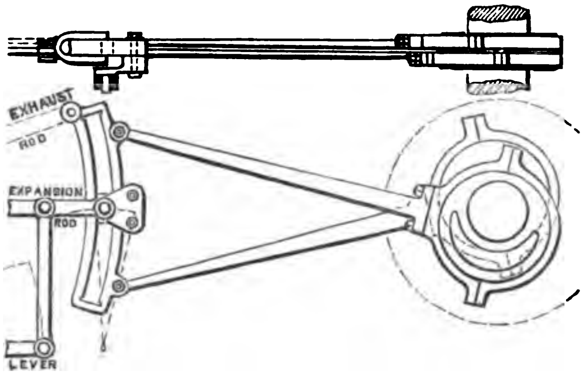
Fig. 100.



Spencer's Single Eccentric Twin Link-Motion for Reversing and for Working the Main and Expansion Valves; also shown in Section, with the port plate between them, patented in the year 1863.
]

The illustration, Fig. 101, is a side elevation and plan of valve gear having a single fixed link and two eccentrics of different throws, or a different amount of travel for the valves; both eccentrics being shown as set for forward motion; the expansion rod when up is for a maximum admission, and when down for a minimum admission. In the elevation the horizontal rod, situated between the link and the valve, is the expansion radius rod; whilst the rod in dotted lines and shown at an angle and above the expansion radius rod, connecting the upper end of the slotted link, is the exhaustion radius rod. Between the link and the eccentric the upper rod may be assumed as having four-inch travel; whilst the lower rod is connected with the eccentric of shorter throw, or having a travel of, say, two and a half inches. The lever working upon the weigh shaft, may have its position changed by means of a hand lever operated in the usual way, or it may be so actuated by a governor as to regulate the degree of expansion which may be necessary or required according to circumstance.

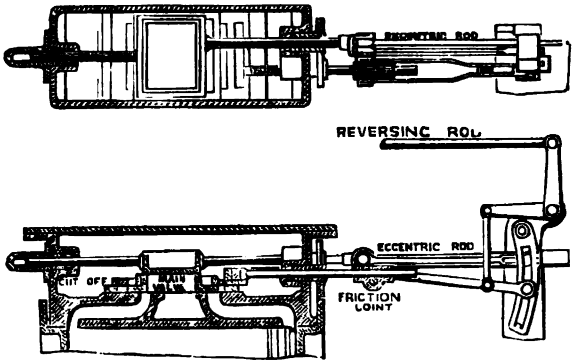
Fig. 101.



Spencer's Twin Eccentrics, *fixed* Link-Motion for working the Main and Expansion Valves, patented in the year 1863.

Just before Mr Spencer's patent was sealed, another patent, Mr. Brown's of Cheshire, was settled for his invention of arranging main and cut-off valves to be worked by a *single* eccentric and *single* link, which, unlike other arrangements of this class, had the link separately situated directly in front of the valve casing instead of being formed with the band of the eccentric; thus reducing the details in comparison with the double eccentric order, and supposed to accomplish a similar effect as the double link. The illustration, Fig. 102, is a sectional elevation and plan of the valves and gear. The cut-off valve is made to work on the back of the main slide valve, which is so formed as to have its flanges produced with two ports or openings therein. The cut-off valve has also its flanges produced with two ports similarly, one of which always coincides with one in the main slide valve at the extremities of its stroke, while the other port is closed. The main valve is worked in the usual way by an eccentric rod and valve rod, and the latter may be, for convenience of arrangement, carried through the back of the valve casing or chest, as shown. The cut-off valve may be also worked from the back of the casing or valve chest, but in the illustration they are both represented as being worked from the front of the valve casing, the cut-off valve being also worked by a rod—both the rods being side by side. Upon this rod is mounted a friction sliding joint that is worked by the slot link, which is suspended from a fixed centre. This slot link is actuated by a connecting rod from the main valve-

Fig. 102.



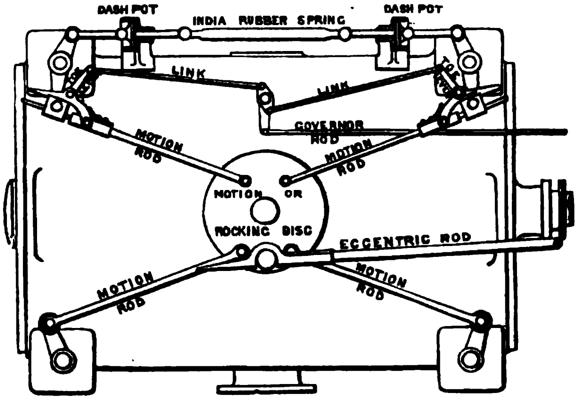
Brown's arrangement of Cut-off and Main Valves, with a Single Link and Eccentric Motion, patented in the year 1863.

rod joint, and by this arrangement the speed or the extent of the travel assigned to the cut-off valve varies with the position of the working block in the slot link, but as the travel of this valve on the back of the main one is just sufficient to close one port and at the same time open the other—this amount of travel being shown by the distances of the abutting surfaces of the two valves—and as the cut-off valve, when effecting any degree of expansion, must have a greater speed or amount of travel than that of the main valve, the friction sliding joint moves freely on the spindle after having closed the primary valve port, and thus the steam is regulated.

On page 54, by Fig. 48, is illustrated peculiar vibrating partially cylindrical valves for regulating the admission, expansion, and exhaustion, of the steam into and from the cylinder of an engine; and, by Fig. 49, the arrangement of the gear for that purpose. The principle of that gear is similar to the "Corliss" valve gear invented first and applied in America about ten years ago by a native of that name, and has since been introduced and very much improved by English engineers in this country, and also in Scotland.

The illustration, Fig. 103, represents a side elevation of this gear

Fig. 103.

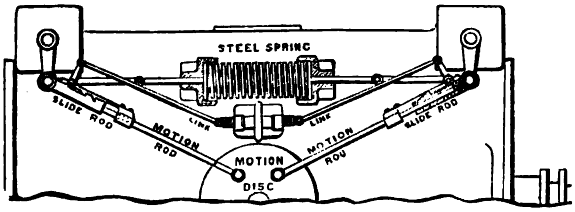


Inglis's "Corliss" Valve Gear, fitted with an India-rubber Spring and two Dash-pots to close the Cut-off Valves, patented in the year 1863.

as applicable for working steam admission valves, when—as in the "Corliss" engine—such valves are arranged to close by the action of weights or springs. This arrangement consists in substituting india-rubber springs or spiral steel springs for the weights or blade steel springs hitherto used in America, the object being to avoid noise and liability to breakage. The admission valves of the steam cylinder are actuated by rocking spindles having levers on their ends. The lower ends of these levers are actuated by motion rods from the rocking disc, which last is worked by the eccentric rod, and which, by the rods, also actuates the levers of the exhaust valves. The upper ends of the admission valve levers are linked to discs, which work in the dash pots, used with this class of valve to prevent concussion. The dash pistons are formed with spindles which work through the backs of the dash pots, and are connected together by the india-rubber spring, one spring thus serving for both valves.

By Fig. 104 a spiral steel spring is shown as applied in a similar way as the india-rubber, excepting that it is connected to the same ends of the valve levers as the motion rods are, and it reacts expansively, whereas the rubber spring reacts by contracting.

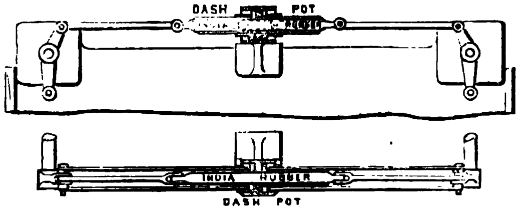
Fig. 104.



Inglis's "Corliss" Valve Gear, with a Steel Spring and two Dash-pots to close the Cut-off Valves, patented in the year 1863.

Fig. 105, on the next page, is sections in plan and elevation, showing another way of applying an india-rubber spring, the two dash pots being in this case formed in a single casting placed centrally, and the springs being placed in a central tube, within which the dash pistons can work. In this class of engine the steam admission valves are opened against the resistance of the springs or weights, and the closing is readily caused—when giving steam through only part of the stroke—by releasing or disconnecting the parts.

Fig. 105.

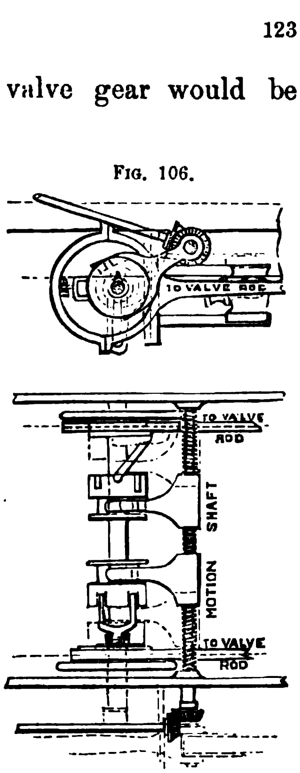


Inglis's "Corliss" Valve Gear, with an India-rubber Spring and Twin Dash-pots in one casting for closing the Cut-off Valves patented in the year 1863.

In Figs. 103 and 104 are shown also two modifications of improved adjustable releasing gear, forming part of this arrangement. In the modification shown by Fig. 103, each rod has jointed to it a catch, acted on by a spring, and arranged to lay hold of the block jointed on the pin of the valve lever, and also to slide on the end of the motion rod. The catch has jointed to it a toe lever or bell crank, which bears on the block, and lifts up and releases the catch at the proper time. The toe lever is connected by a link to a lever, adjustable by the governor rod, or it may be by hand. It will be seen that the relative motions of the parts will cause the release to take place at an earlier or later period of the stroke, according to the adjustment of the lever to which both links are jointed. In the modification shown in Fig. 104, the motion rod is fitted to slide in a short rod jointed to the valve lever, and is held in gear by a spring catch-plate, acted upon by a toe lever, as in the other modification. The links are jointed to spindles, having right-handed and left-handed screw threads, and adjusted by means of a hand wheel internally screwed to correspond. When the adjustment is effected by means of the governor, a spring may be introduced to act in the opposite direction to the governor.

In the year 1864 Mr. Taylor and Mr. Dow of Stratford, Essex, were filled with the idea that by shifting the eccentric on its axis in a line with its motion, the requirements of perfect valve gear would be accomplished, as illustrated by Fig. 106.

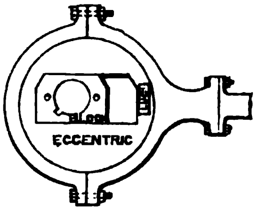
Fig. 106.



Taylor's Shifting Eccentric Valve Gear as applied to a Locomotive Engine, patented in the year 1864.

The eccentric, illustrated by Fig. 107, according to this arrangement, is mounted on a block or centre piece keyed on the crank shaft, or it may be on an additional eccentric shaft, the eccentric being so fitted thereto as to be rigidly carried round with the block, but also that it may be slid in the direction of its diameter, or nearly so: it is supported on either side by cheek plates from the block. From the eccentric strap a connecting rod leads direct to the valve rod as in an ordinary fixed eccentric. At a little distance from the eccentric block is placed a piece somewhat resembling the sliding part of a shaft clutch, and like it sliding on the shaft, but carried round by a feather, and having a groove around it, to which the ends of a forked arm clasp, for the purpose of sliding it towards or from the eccentric; on the side next the eccentric the sliding piece has a central boss or projection, which is embraced by the forked end of a link jointed thereto; the other end of this link is extended towards the periphery of the eccentric, near which it is attached by a joint pin to suitable lugs projecting on the side of the eccentric. When the sliding piece is at its farthest distance from the eccentric, the connecting forked link assumes a position at about an angle of forty-five degrees to the centre line of the shaft, but when moved closer to the eccentric it approaches towards a right angle thereto. The traverse of the sliding piece on the shaft produces this effect, and at the same time causes the eccentric to traverse somewhat in the direction of its

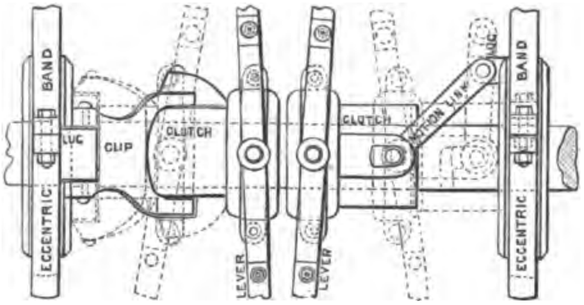
Fig. 107.



Detail of Taylor's Shifting Eccentric, patented in the year 1864.

diameter, and to transfer the point of greatest eccentricity from one part of its circumference to another, and so produce a corresponding change in the position of the valve with which it is in connection. This is shown in two positions by Fig. 108. Instead of moving in a direct line the eccentric may move in a curved course on its supporting block, which may be desirable to give the requisite lead—at all points of the traverse—to the steam when the engine is moving in one direction or the other, and to give the desired lap to the valve to work somewhat expansively.

Fig. 108.

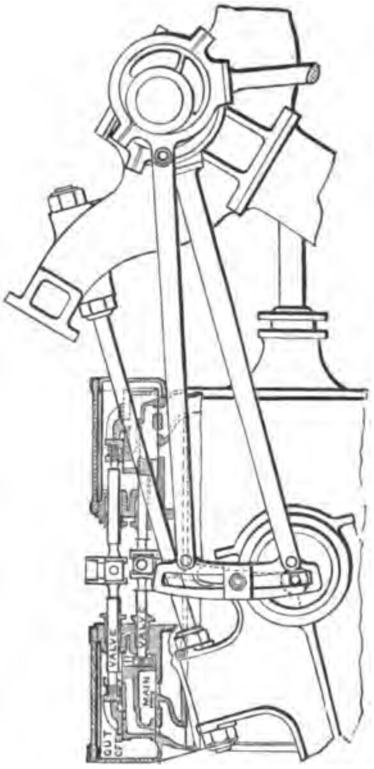


Taylor's Shifting Eccentric Valve Gear, shown in two positions at right angles with each other, patented in the year 1864.

To actuate the sliding or fork block before mentioned, the motion shaft, as shown by Fig. 106, is used parallel with the eccentric shaft with a right and left-hand screw upon it, and on each screw is mounted the forked arm before mentioned—one for each eccentric—and by rotating the screw shaft the forked arms traverse thereon, and cause the sliding blocks to move farther from or nearer to the eccentrics, and so produce the changes desired. To impart motion to the screwed shaft for locomotive engines, as in Fig. 106, a bevel wheel is placed on the end, gearing with another bevel wheel on the end of a shaft, whose opposite end carries a hand wheel in position over the foot plate, to be conveniently accessible to the engine-driver.

In the same year Mr. Löbnitz of Renfrew, N. B., patented a peculiar arrangement of valve gear especially relating to compound oscillating paddle-wheel marine engines, worked by high and low pressure steam, the areas of the cylinders being arranged in accordance with the difference in the pressures. The arrangement of the valves and gear is shown by Fig. 109, as arranged for an *angular* oscillating engine. The main slide valves on the cylinders of this engine are worked by one motion shaft, the one end of the lever of which is brought out by a bend to the centre of the trunnion of either the large or small cylinder, and is directly acted upon by an eccentric or other means from the main shaft, without being transmitted through a quadrant or sweep, such as is used in ordinary oscillating engines. The other end of the said lever is connected direct to the valve rod when the cylinder is arranged with two valve casings; the motion shaft or lever works between, and when only one valve casing is applied the motion is transmitted by a connecting rod to another motion shaft that gives the motion to the two valves of the same cylinder. The main and cut-off valves can be understood from the illustration. When compound cylinders are used, the high pressure steam is admitted first through the trunnion of the small cylinder, and after having acted in it passes through an exhaust passage into the large cylinder, and after doing duty there passes into the condenser.

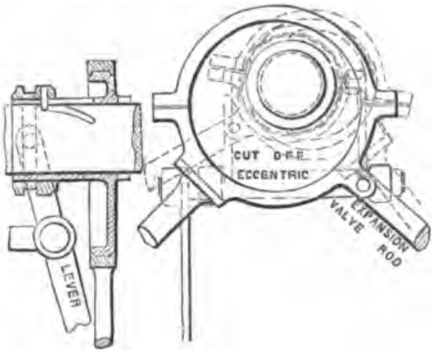
FIG. 109.



Löbnitz's Arrangement of Main and Cut Valves, with Link Motion and Expansion Gear for working them, for Oscillating Marine Engines, patented in the year 1864.

The eccentric motion for the working of the cut-off valves is illustrated in detail by Fig. 110, on the next page, which is a section and end view of the variable cut-off eccentric attached to a long cylindrical boss surrounding the shaft. In this boss is cut a slot, parallel or inclined to the centre line of the shaft, in which slides the pin fixed on the clutch; the point of the pin is further let into an angulated slot in the shaft, and by moving the lever within a quadrant, the clutch will be shifted and move the pin, which is guided in the slot, and thus shift the variable cut-off eccentric to any desirable position, and accordingly the valves will cut off the steam at any point required while the engines are in motion.

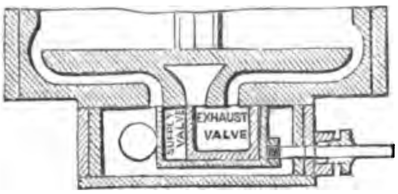
Fig. 110.



Löbnitz's Variable Eccentric Expansion Gear, adjusted by a Sliding Clutch and Lever, patented in the year 1864.

At the end of this period, 1864, Mr. King, an engineer of Gloucestershire, with two others named Smith and Howell, patented a peculiarly arranged valve and gear, to attain, as they presumed, all the ends dependent for the perfect control of the steam. Their contrivances partly consisted in the adoption of two slide valves one *within* the other, as illustrated by Fig. 111, which shows that there is a separate valve for the exhaust, contained in that for the supply of the steam. The supply valve is worked by the valve rod in the usual manner, while the exhaust valve, which is fitted sideways, and at the back accurately, is within the cavity of the supply valve, but in length is considerably less than the said cavity, and has a small **V**-shaped space between the ends when in contact in either direction, as shown. This inner valve has no separate or special rod, or other connection, but depends for its motion on the working of the outer valve, and the steam pressure traverses it towards the opposite end immediately steam is admitted to either end of the cylinder, which has the effect of opening

Fig. 111.

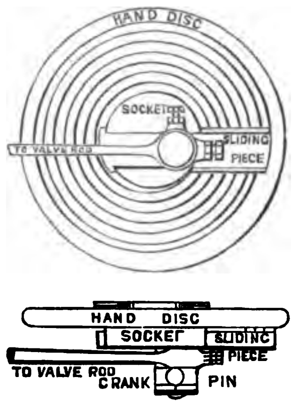


King's Double Valve, for Variable Cut-off and Ample Exhaustion of the Steam for any Grade of Expansion, patented in the year 1864.

the exhaust port simultaneously therewith, and allowing it to remain open during the greater part of the stroke, although the steam may be cut off at a quarter or other fractional part of the stroke.

Mr. King's ideas of valve motion are illustrated by Fig. 112, which is an apparatus for varying or altering the position of the eccentric or crank pin by which the slide valve or valves are driven, and whereby the extent of motion is to be regulated, or the motion reversed. To effect this, the valve rod is driven from a crank pin, and this crank pin is fixed in a dovetailed sliding-piece, dovetailed into the socket that is fixed or formed on the crank shaft. This dovetailed socket is across, or nearly so, the axis of the shaft in which direction it slides; it has feathers or projections on the back part, which fit into a spiral groove cut in the hand disc, which is mounted loosely on the shaft. This disc, if not acted on by any separate means, rotates at the same velocity as the shaft, and the crank pin maintains the same radius. In the position shown the crank pin is at its extreme radius, giving the valve its greatest extent of motion, consequently admitting steam throughout the length of the stroke. If it is desired to give the valve less motion it is simply necessary to impart rotation by hand to the disc at a little quicker rate than the motion of the main shaft, which will cause the spiral groove to operate on the feathers and the sliding piece, and traverse it a greater or less distance in the radial direction. To reverse the engine it is simply necessary to traverse the sliding piece, so that the crank pin will pass across the axis to the opposite side of the shaft. To move the crank pin from a lesser to a greater radius it is simply necessary to retard the motion of the disc, and so allow the shaft to run a little quicker than the disc, the effect of the spiral groove being to traverse the piece as desired.

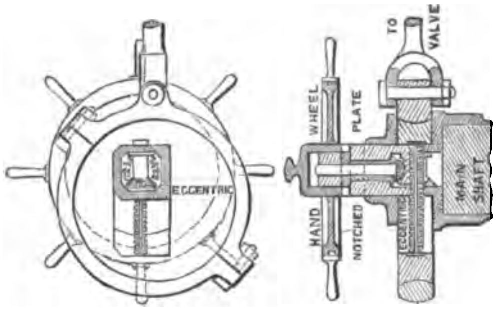
Fig. 112.



King's Spiral Grooved-Disc Valve-Motion, used as Expansion, Reversing, and Stopping Gear, patented in the year 1864.

But Mr. King and his colleagues even thus far had not expended their powers of invention, for they patented also a shifting eccentric motion, and gear attached, which ran away with Mr. Atherton's scheme, dated 1850, as illustrated on page 30 by Fig. 26. Certainly Mr. Atherton made that arrangement as simple as he could, whereas Mr. King and his party introduced bevel gearing; which, by the way, Mr. Atherton did also, to work the screw motion rod; instead of a rack as Mr. Atherton proposed in one case; and the illustration, Fig. 113, represents Mr. King's mode of carrying out the modification in this way.

FIG. 113.

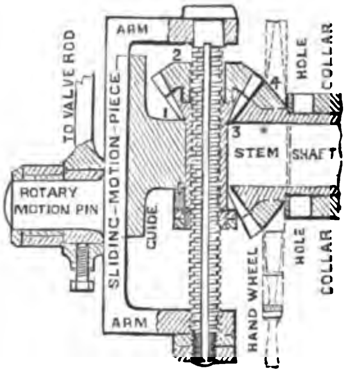


King's Bevel Gearing for shifting the Eccentric when used as Expansion Gear for a Range of Cut-offs, patented in the year 1864.

On the end of the main shaft a hollow casting is fixed, on the square part of which the eccentric is fitted, and furnished with the screw motion rod; on this screw rod is fitted the fixed wheels, one having a screwed boss fitting the other wheels, and connected by a feather and groove; a pinion gears with the wheel that carries on its shaft the hand wheel, while the other pinion gearing with the other wheel has fixed on it a notched plate, which may be fixed by a bolt fixed to a part of the framing, while the hand wheel may be fixed or loosened by a clutch piece on the shaft. This gear answers the purpose of traversing the eccentric to a greater or lesser radius, by rotating the hand wheel in the same or reverse direction as the motion of the shaft, during which time the hand wheel is to be clutched to the smallest pinion, and the largest pinion prevented from rotating by the bolt.

Last, but not the least, of Mr. King's patented proposals, is his modification as illustrated by Fig. 114, on the next page, which represents, that in the end of the main shaft is inserted a stem-shaft, and on its extremity is a guide dove-tailed inward, to receive into the channel a sliding motion piece, which has formed with it a pin and arms: the latter being in connection with the "screw motion rod," that adjusts the travel for the valve. This rod has fitted around it two bevil pinions, the smaller, 1, being as a nut on the rod and the larger, 2, being loose thereon, but has a feather in the boss which slides in the groove in the screw motion rod, causing it to rotate therewith; the pinion 1 revolves independently of pinion 2, and has a tube piece passing through the stem shaft, in which it is free to rotate. Bevil pinion 1 gears with another bevil pinion 3, that is fixed on a round part of the stem shaft, while pinion 2 gears with bevel pinion 4, that is, fitted loosely on the neck of the pinion 3; pinions 1 and 2 have an equal number of teeth, as also have pinions 3 and 4. In one piece with the largest pinion, or fixed thereto, is a hand wheel, as shown dotted: it is arranged that the hand wheel may either be held fast and prevented from rotating, or it may rotate freely with the main shaft; in either case no effect is produced on the sliding motion piece, for when the wheel is held fast, motion will be given to pinion 2 by gearing with pinion 4, as then the former pinion carries the screw around with it and the sliding piece revolves.

FIG. 114.



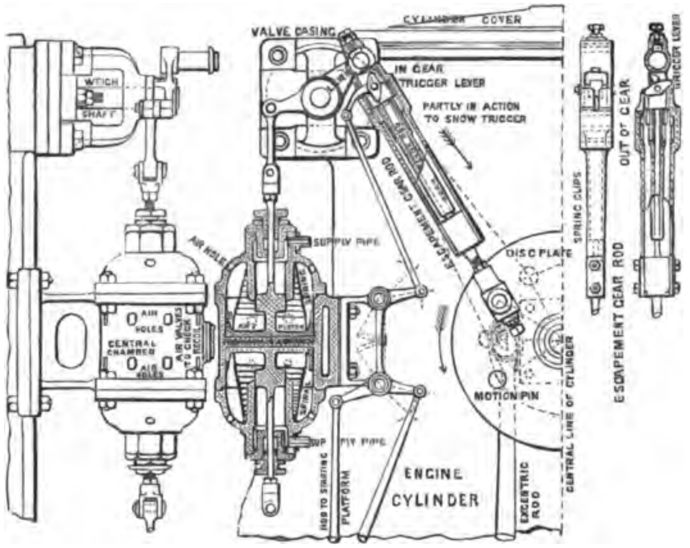
King's Bevil Gearing for regulating the Travel of the Slide Valve when worked by an adjustable Rotary Pin, patented in the year 1864.

It was mentioned that pinion 4 is fitted loosely on the neck of pinion 3, but it is actually fixed to a collar on it, and when the hand wheel is fixed, the collar is also held fast, by slipping a bolt, mounted on the bearing or frame, into one of the holes shown. The rotation of pinion 1 with the shaft will produce a rotation on its own axis by reason of its gearing with pinion 4—which is locked as above mentioned—and will neutralise the effect of the rotation of the pinion 2 on the screw rod, which will therefore maintain the same relative position.

Supposing it is desired to vary the position of the screw rod, and with it the crank pin, the hand wheel, and with it the pinion 4, is to be turned in the same or in an opposite direction to that of the rotation of the shaft; the pinion 2 will then receive a motion at a velocity greater or less than the motion of pinion 1, which will result in a differential motion being imparted to the rod, and consequently a shifting of the rotary motion pin to a position having greater or less throw or eccentricity, such as may be desired; the same action will have the effect of traversing the pin across the guide in order to reverse the engine.

At the beginning of the year 1865, Mr. J. F. Spencer again applied his inventive powers to valve-gearing, but this time to the "Corliss" appliance, as illustrated by Fig. 115, which is front and side elevations of a part of a steam cylinder sufficient to show the valve gear referred to, and also the improved escapement gear rod by itself; a portion only of the engine cylinder is shown, and such cylinder may be vertical, horizontal, or inclined, without impairing the usefulness of the improved

FIG. 115.



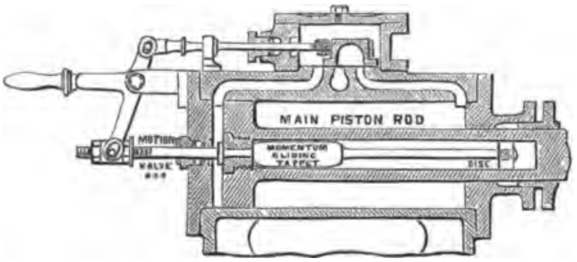
Spencer's "Corliss" Valve Gear; being the application of Atmospheric Pressure in combination with Steel Springs to close the Cut-off Valves, patented in the year 1865.

valve-gear; also is shown a portion of the valve casing in which may be one of the ordinary steam admission ports and a plain slide valve made to cover the ports with sufficient lap to prevent leakage and to suit the action of the valve. The port and slide faces may be flat or curved according to the plan adopted to move the valve; the slide valve is worked by drivers on a weigh shaft, passing through a stuffing box; this weigh shaft might give motion to any other kind of valve which requires little power to move it. But in the present illustration a valve commonly called the "Corliss" valve is supposed to be used; a rod worked by an eccentric or crank on the main crank shaft, or on a supplementary shaft, is driven by the crank shaft, and the reciprocating motion of this rod causes the disc plate to vibrate on a pin. On the disc plate are four pins, two of which only are shown, and one of these gives motion to the escapement gear rod, which is attached by a pin and lever to the weigh shaft, which imparts motion to the valve for admitting steam to the cylinder. The escapement gear rod consists of two principal and distinct parts, and one of which is always connected to the motion pin on the disc plate, and the other to the lever pin. There are two steel spring clips bolted to that part of the escapement rod which is attached to the disc pin, and these spring clips are connected to that part of the escapement rod which is attached to the lever pin by the grip of the projecting edges of the hardened steel tubing. The trigger lever, toe piece, or trigger works on a pin within the tube, and is connected by rods, &c. to an adjustable handle accessible to the engineer in charge. When the engine is started, and the escapement rod is in gear, as shown in the illustration, the motion of the disc plate and escapement rod, in the direction of the arrows, brings the trigger lever in contact with the insides of the spring clips, and throws them out of gear, and the admission valve is instantly closed by the action of a spring or weights acting on the top lever and weigh shaft; and the time that the clips are disengaged and the admission valve is closed, can be varied as required by the relative position of the trigger lever, which is held in any position at the discretion of the engineer in charge by the rod, or the rod may be connected to a governor which regulates the speed of the engines by the amount of the steam admitted by the valves. The two parts of the escapement rod before described are shown in the illustration as guided in the same line of motion by a guide rod and bush.

The escapement gear rod is also shown disengaged; the steel spring clips being pressed outwards by the pressure of the toe or trigger, and therefore allowing the loose tubular parts of the escapement rod to be separated by the closing action of the slide valve.

It will doubtless be remembered that on page 58 we illustrated by Fig. 51 an arrangement of "self-acting valve-gear," which was regulated by steam, and we now illustrate another self-acting arrangement, which depends *entirely* on the momentum of a sliding block of metal, which of course "must never stick or hang fire." To enable this to be fully appreciated, we illustrate it by Fig. 116, which shows a longitudinal section of a cylinder, having within it a piston and a hollow piston rod, within which a motion rod works, having a disc thereon that supports the rod centrally within the hollow piston rod. On the motion rod, and within the hollow piston rod, is a sliding momentum tappet, which slides freely on the motion rod. The outer end of this rod is connected with a lever, which at its other end is connected with the spindle of the slide valve. On the lever is a handle

FIG. 116.

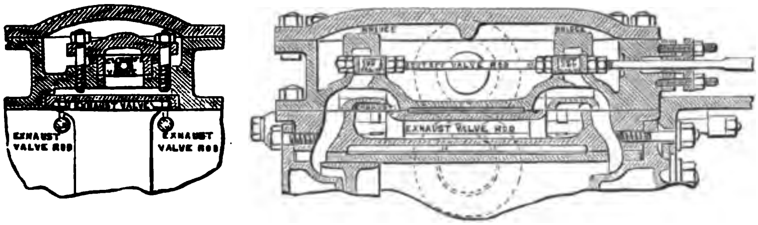


Jones' self-acting Valve-Gear; regulated by a Sliding Loose Block, termed a "Momentum-Sliding-Tappet," patented in the year 1865.

by which the valve may be moved when desired, and supposing the piston should be started from the position shown in the illustration and not arrive at the end of the stroke, the tappet would continue its motion and would reverse the position of the slide valve. If desired, the tappet and its rod which is in connection with the valve spindle may be wholly external of the engine and away from its piston rod, but suitably in connection or communication therewith, so that it may have a capability of movement, and continuing its action on the valve after the piston has ceased to act. But it is not essential that the tappet or instrument acting on the valve of the engine should slide on a bar; on the contrary, a tappet or instrument on an axis put in motion by the piston of an engine, and acting on the valve of the engine, may be used, such tappet or instrument being arranged to continue its rotation by momentum after the piston has stopped.

We now advance to the year 1866, and notice next that Mr. Porter received a communication from Mr. Allen, who patented the arrangement of valves and gear as illustrated by Fig. 52 on page 59, and preferred after to use them as shown in two sectional elevations by Fig. 117.

Fig. 117.



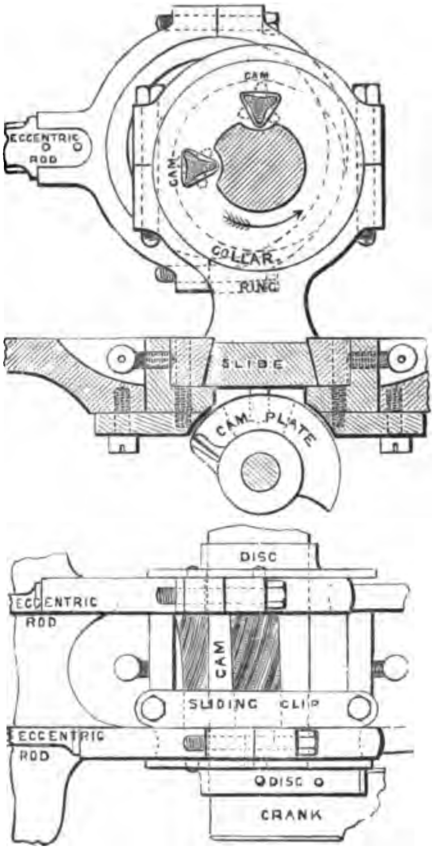
Allen's Equilibrium Cut-off and Exhaustion Valves for regulating the Steam to and from the Cylinder of an Engine, patented in the year 1866.

The supply ports are formed in the port face, and communicate with each end of the cylinder in the usual manner, as shown. The cut-off valves, which are fitted to slide on the port faces serve only for admitting and cutting off the steam, the additional or exhaust valves being provided to control the escape or exhaust of the same. These valves slide upon the facing over the exhaust ports, and are so arranged and operated as to close the latter when the communication between the corresponding end of the cylinder and the steam chest is open. The other valves are each constructed in the form of an oblong frame whose surfaces are parallel; the lower surface is fitted to slide upon the port face, while the upper surface works in contact with the under surface of the plates or bridges which prevent the pressure of the steam on the back of the valves. Each of the latter is constructed with a boss, through which the rods pass, the said rods being secured therein by the adjusting nuts. These valves are operated by their rod, while the exhaust valves are operated by the lower rods; all of the said rods being connected to separate levers on the rocking shaft or other convenient working part of the engine. The left-hand cut-off valve is shown opening the port, while the right-hand valve is moving towards the forward end of the cylinder, and keeping closed the apertures, which all communicate with the other port, that admits the steam into the cylinder at that end. These apertures, which equal the effective area of the said port, increase in width as the valve moves forward till the edge of the valve reaches the middle of the port, at which point the areas of all of those apertures are equal to the port.

In the same year, 1866, a Mr. Chapman of Lincoln proposed to substitute for the link motion his arrangement of eccentric-gear, as illustrated by Fig. 118, in the following manner:—

To the inner side of each crank is bolted or otherwise fixed a circular disc, between which discs the eccentric bands are attached and arranged thus. Each eccentric has fixed to it and projecting from the inner face thereof a twisted cam, somewhat in the form of a quick-threaded screw, the ends of the said cam being pivoted into both discs, and thus each cam forms the centre of motion of its respective eccentric band. The ordinary eccentric rods and bands are shown: one eccentric for reversing only being required for each slide valve for two engines; the cams are enclosed by, and pass through openings in, a sliding clip; this clip is capable of sliding on the crank shaft between the two eccentrics, and it is evident that as it is moved from one to the other the action of the sides of the openings against the cams will impart a partial revolving motion to the latter, and hence the position of the eccentrics with regard to the cranks will be reversed, and consequently the crank shaft would be caused to revolve in the opposite direction to the arrow. It will also be evident that the eccentrics can be caused to assume any intermediate position, and therefore to give any required amount of expansion by moving the clip a portion of the distance only. The cause of the sliding of the clip on the crank shaft is shown in the elevation, which is by a ring embracing the collar that is connected to a slide piece working in a groove in the bed plate. From the under side of the slide projects a pin which fits in a groove in the twisted cam-plate keyed upon a transverse shaft, upon one end of which is also keyed a lever connected to another lever by a link: this lever is provided with a bolt working in notches of a quadrant, and by means of this lever the position of the eccentrics and consequently the direction in which the engine revolves—and the amount of expansion at which the steam is worked—are controlled.

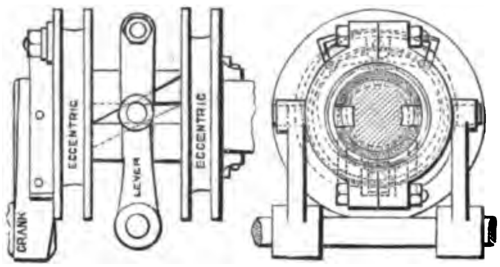
Fig. 118.



Chapman's Adjustable Eccentric Gear, proposed as a Substitute for the Link-Motion, patented in the year 1866.

Mr. Chapman proposed also a modification of his first arrangement for shifting or sliding the clip by direct levers, as shown by Fig. 119 on the next page. In this modification each eccentric band is situated also between two discs. The outer discs, which are bolted to the cranks, are provided with slightly curved horizontal slots, so arranged that a constant lead is maintained, and the inner discs with radial slots. The pin which supports the eccentric band passes through the slides, which work in these slots. The eccentric band is also provided with a guide pin, which works in a similar slide moving in a radial slot in the disc. This modification may also be used as a fixed eccentric to be set at any degree of expansion, and fastened with the nut without the shifting gear.

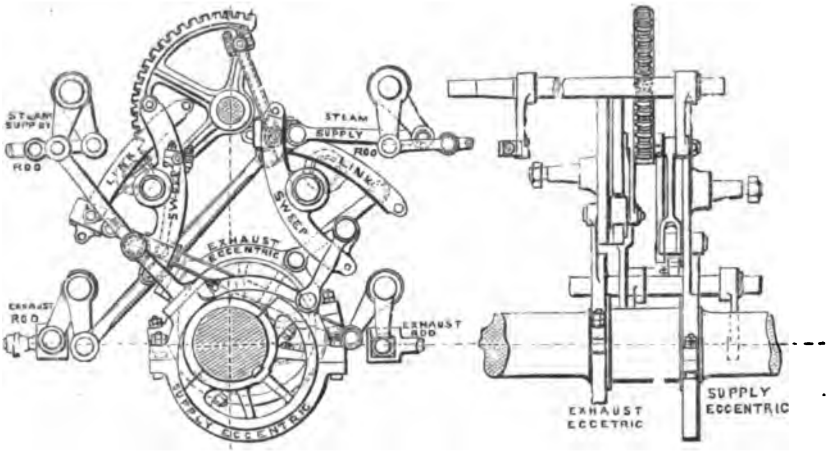
Fig. 119.



Chapman's Adjustable Eccentric Gear, proposed as a Substitute for the Link-Motion, patented in the year 1866.

In the smiling month of May, 1867, Mr. Henry Turner patented an arrangement of link-motion valve-gear, which must have cost him a deal of time, and no end of trouble, to have conceived; and the birth of it must have been a happy deliverance for him. But to enable the gear to be appreciated justly, we must first inform our readers to what class of engines it was fitted. The arrangement consisted of four cylinders, two high pressure and two low pressure; the high-pressure cylinders exhaust their steam into the low-pressure cylinders, and the steam is from thence exhausted into the condensers. Two cylinders are fixed on one side of the main cranked shaft, namely, one high pressure and one low pressure, and other two cylinders, one high and one low pressure, are also fixed on the opposite side of the main cranked shaft; the whole four of these cylinders are in the same horizontal or vertical plane, as required, and are fixed in the positions described. The steam will exhaust in the most direct manner from the high-pressure cylinder, after having done its duty there, into the low-pressure cylinder, by passing through a passage at the same end of each cylinder in combination —one high and one low pressure—and equidistant from the centre line of the engine shaft. Both ends of each high-pressure cylinder have a communication across in the shortest direction with both ends of the low-pressure cylinders, so as to bring the waste of steam in the passages to the smallest limit. To effect this purpose the two cylinders, high and low pressure, working in conjunction, must have their respective pistons working in opposite directions at the same period. In these engines the above-named object is obtained by fixing firmly in the forward frame of the engines, that is to say the frame farthest removed from the work or resistance which has to be overcome by power, and on the centre of the circle of the main engine shaft, a stud or pivot on which a crank lever is allowed to work freely; this crank does not transmit any power from the engines, but acts only as a radius guide or link to the forward engine crank pin. The forward cylinder is made high pressure in these engines for convenience, but could be made low pressure if required. One end of the radius guide shaft works freely on the stud or axle; the other and opposite end has a crank pin fitted or forged on, to which the connecting rod of the forward engine gives a circular motion around the axis of the shaft: one end of this crank pin is attached to the crank lever; the other end has a circular piece forged on it, forming a bearing for a connecting link or rod which is made of a sufficient length to form a communication at the opposite end with another crank pin on which the connecting rod of the cylinder opposite works, and which cylinder is fixed on the other side of the engine main shaft. The slide valve-gear, as shown in two views by Fig. 120 on the next page, is arranged in the following manner:—Two eccentrics are keyed or otherwise fixed to the engine axle or shaft. One of these eccentrics works two supply steam valves, and the other one works two exhaust valves; these exhaust valves form the outlet from the high-pressure cylinders and the inlet into the low-pressure cylinders, and also the exhaust from the low-pressure cylinders into the condensers. Two rods are attached to each eccentric band; one rod is firmly fixed or bolted to the band, the other rod has a jointed end which works loosely on a pin. The foot of the first-named rod and the boss for the pin on which the second rod works are ninety degrees asunder. Each of these rods works a lever, to which lever is attached a sweep, the radius of which is pointing towards the slide valve instead of towards the engine shaft as is usual in the ordinary link motion. Each sweep is provided with a sliding block, which is raised and lowered above or below the pivot, on which the sweep works, imparting a forward or backward motion to the above-named connecting rod, according to which side of the pivot the sliding block is situated at the time. These rods are connected at one end to the sliding blocks, the other end to the levers giving motion to the slide valve rods. The supply steam slide valves are quite independent of the exhaust slide valves, as they are worked by two separate eccentrics, the lap and lead of each kind of slide valve can therefore be made different also, and suitable to every case. The four sliding blocks, two for working the steam valves, and two for working the exhaust valves, are raised or lowered altogether and at the same time by means of the suspending links: the worm wheel is shown, but the worm, whose shaft is connected to a starting wheel, which is common to and moves all the four slide valves at the same time, is omitted.

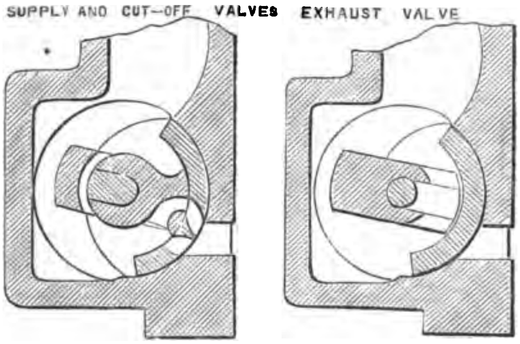
FIG. 120.



Turner's Link-Motion and Valve Gear, for high and low pressure combined, Marine Screw Engines, patented in the year 1867, and fitted to the engines put in the Greek Gunboat "King George," by the Thames Iron Works Company.

Our next example of valves to be noticed is of the "Corliss" class, being something similar to those illustrated by Fig. 48 on page 54. Mr. Wood, of Bolton, patented these valves, as shown by Fig. 121, and he also patented their arrangement and gear as shown in three views by Figs. 122 and 123 on the next page.

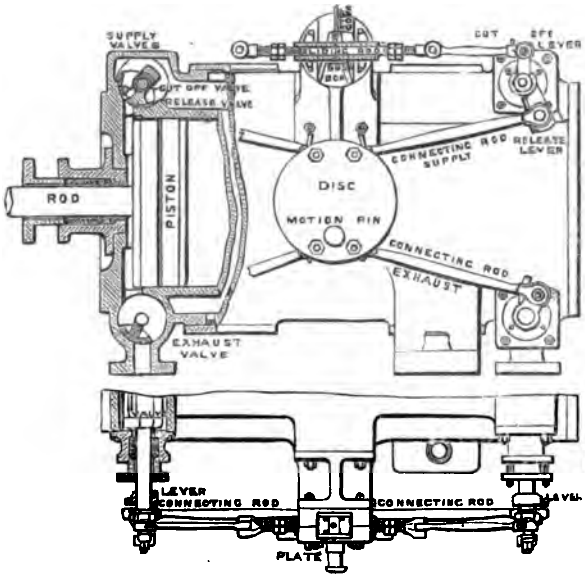
Fig. 121.



Wood's "Corliss" Valves, for Admission, Cut-off, and Exhaustion, separately, patented in the year 1867.

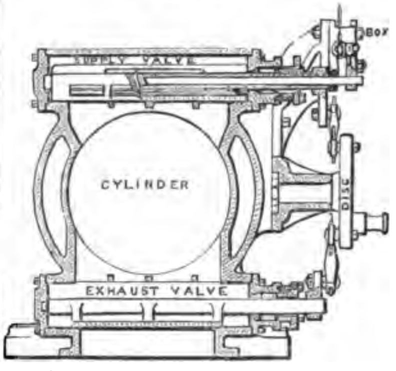
The supply and release seating valve, consists of a segment of a hollow cylinder, having a reciprocating or oscillatory motion from its rod, and is made long enough to fill the steam chamber. In the face of the said valve and through it are two lines of passages or openings cut in the direction of the rod of the valve, having the same breadth of opening in the outer circumference of the valve as in the steam port of the cylinder, and on the inner circumference the division is widened to the extent of the cover or lap; so that the cut-off valve when so placed that the aperture or opening is exactly over the division betwixt the passages, will have sufficient lap to be steam-tight; also this valve or movable seating has pieces cast on each end forming the sector of a circle, which pieces are cut out in the direction of its radius to the diameter of the spindle. The ends of the pieces are accurately fitted on to projecting arms, as shown in the elevation, formed on the hollow spindle, so that any motion communicated to the said hollow spindle may be transmitted to this valve. This same hollow spindle is so constructed that a part of it in the direction of its length is cut out equal in length to the boss of the cut-off valve, which boss occupies the space so cut out, and the two ends of the said hollow spindle are joined together by a bar or bridge at a sufficient distance from the centre to clear the boss of the valve. The extreme ends of the hollow spindle

FIG. 122.



Wood's "Corliss" Valves and Gear, in elevation and plan, being, three distinct Valves at each end of the Cylinder for "Admission, Cut-off, and Exhaustion," with the Corresponding Gear, all under the control of the Engine Governor, patented in the year 1867.

FIG. 123.



Wood's "Corliss" Valve Gear, in transverse Sectional Elevation, being the corresponding view to those shown by Fig. 122, patented in the year 1867.

are cylindrical, the one working in the chest cover, and the other protruding through a stuffing box. This end of the spindle has a lever fastened on it, and beyond that is a screwed cap or stuffing box to prevent leakage. The lever or arm is connected by a rod to a disc having a reciprocating motion imparted to it by an eccentric and rod or their equivalent attached to and operating on the stud or pin.

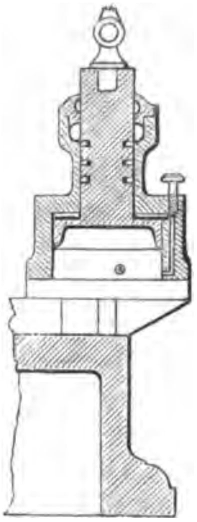
The cut-off valve is of the same principle of construction as the release valve, and similar in configuration to the "Corliss valve," but has only one opening or passage cut through it, and has a reciprocatory or oscillatory motion for a certain limit like the other valve, on the back of which it may be retained or kept in position either by steam pressure or by springs. The boss of the cut-off valve is made with an oblong hole through it so as to allow for wear on the face thereof, and fitted into this hole is a fast key or feather having a corresponding groove cut in the spindle, into which the fast key or feather is made to fit easily; the motion, therefore, of this valve is communicated to the spindle which works inside the outer hollow spindle, and through which it protrudes and terminates; in or affixed to it is an arm or lever which is connected to a sliding rod by a connecting rod. This rod works in two bushes placed in a cylindrical box, in such manner that they have a limited motion in the direction of the sliding rod. These bushes are cylindrical at their outer ends, and have a square section at their other parts. In the ends are grooves cut at an angle to suit angular guides formed on plates which are placed on either side of, and have a motion at right angles to that of the bushes. The plates work in a chamber or cell in the cylindrical box, the said plates being fastened together and connected by a rod to the governor, so that any variation thereof will give motion to the plates up or down, and thereby cause the bushes to move either outwardly or inwardly, as the case may be; the said bushes coming in contact with the adjustable stops or nuts on the rod either at an earlier or later point of the stroke, thereby arrest the motion of the cut-off-valve on the back of the release valve, and consequently cutting off the steam at an earlier or later portion of the stroke, according as the varying engine load to be overcome may determine.

The exhaust valves are worked in the same manner as the top valves, and are fitted to arms or levers on a spindle by the same method, and also derive their motion from the same disc.

In the same year Mr. Wood invented the steam "dash-pot" as illustrated by Fig. 124 on the next page, which represents a vertical section of an arrangement of steam piston and cylinder to be employed for closing the valve when released from the eccentric rod's motion, and the adaptation of a steam buffer to prevent concussion on the closing of such valve.

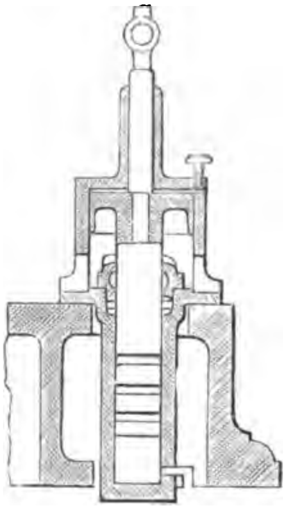
Fig. 125 represents a similar arrangement of apparatus for closing the valve by means of steam, in which air is employed in the "dash-pot" as a medium instead of steam for preventing concussion on the closing of he valve.

FIG. 124.



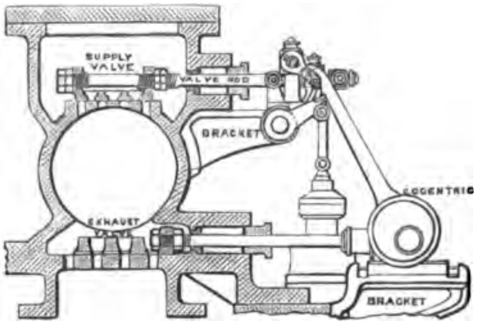
Woods' "Steam" buffer or "Dash-pot," for closing "Gridiron" Slide Valves or "Corliss" Valves, patented in the year 1867.

FIG. 125.



Woods' "Steam" and "Air" "Dash-pot," for closing "Gridiron" or "Corliss" Valves, patented in the year 1867.

FIG. 126.



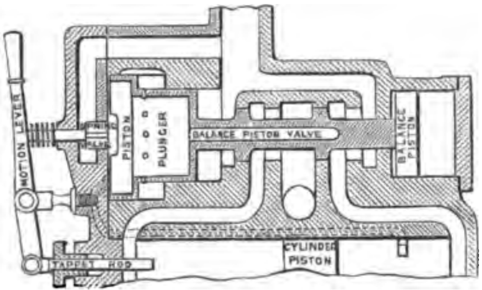
Woods' arrangement of "Gridiron" Valves, for Admitting, Cutting-off, and Exhausting the Steam with "Dash-pot," Eccentric and Lever Gear for working them, patented in the year 1867.

Instead of the "Corliss" valves, Mr. Wood proposed "gridiron" valves, to admit, cut-off, and exhaust the steam, and a transverse section of the cylinder, valves, and elevation of the gear are shown by Fig. 126. The eccentric secured to the rod, is employed to actuate the gridiron slide valve, by means of the following arrangement of mechanism, and in such a manner that the amount of steam admitted into the cylinder for expansion may be "cut off" by the valve at any required portion of a stroke that will be in accordance with the amount of power required for the engine's duty, a separate cam or eccentric being used to actuate the exhaust valve. The eccentric rod projects at an angle from the band or strap of the eccentric towards the slide valve rod, a portion of the upper end thereof being so curved or bent as to become an inclined surface, that bears or slides upon the pin and forms the termination of the lever or arm, which lever is secured to a shaft actuated by the governor, whereby the position of such pin is varied or regulated; a catch or projection being provided on the rod of the eccentric below the bent or inclined surface. In order to effect the opening and closing of the "gridiron valve" so as to regulate the flow of steam into the cylinder, the cross head of the valve spindle is connected by means of the rods with one end of the bell crank lever, the opposite end of such lever at the point being turned up so as to fit and catch beneath the notch on the eccentric rod when it is descending, by which contact during such descent the valve is opened and admits steam.

When sufficient steam is admitted, the rod of the eccentric is immediately disconnected or thrown off the notch or point of the bell crank lever by the position of the pin, which is regulated or decided by the governor, and as soon as the lever becomes released it is forced upwards by means of the steam piston in the cylinder of the dash-pot—as shown in section by Fig. 124—which is arranged at any convenient position, or springs or weights may be employed so as to close the valve, the cranked lever being connected therewith by the rod; while the concussion is prevented by means of the "dash-pot" or buffer, as arranged in Fig. 126, by the employment of steam, which is admitted to the upper portion above the piston through the channel or port. The arrangement for preventing the concussion on closing the valve, as seen in Fig. 125, is effected by air which enters the cylinder above the piston through a passage. It will thus be seen that the bent inclined surface of the eccentric rod during its rise and fall will come into contact sooner or later with the pin in descending, the position of which is regulated by the governor, according to the position into which the notch is brought to come into contact with the projection, which in its descent forces down the lever, and opens, through the medium of rods connected to the valve spindle, the "gridiron" slide valve a certain distance for admitting steam, which is regulated according to the duration of contact between the bent inclined surface and the adjustable pin, that is determined by the governor. When the eccentric rod is unhooked, the steam piston in connection with the lever closes the valve as described, the levers and rods in connection with the valve spindle remain disconnected, and in disuse until again caught, during the descent of the eccentric rod, at which time the valve is again opened.

On page 58 there is an illustration shown by Fig. 51 of an arrangement of steam self-acting valve-gear, patented in the year 1862, and on page 132 by Fig. 116, another arrangement for the same purpose is shown; and again we show by Fig. 127 a third proposal by Mr. Brown of Surrey, which he patented in the year 1868; his idea was to make a balance piston valve to perform the regulation of the admission, cut-off, expansion, and exhaustion of the steam, and to cause the steam to actuate the valve, or similar as that done before by the other arrangements referred to.

FIG. 127.

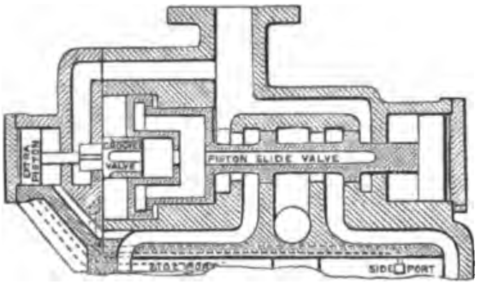


Brown's Self-Acting, Balance Piston, Valve Gear (regulated by a Spring and Tappet rod), patented in the year 1868.

In the present case the valve termed a "balance piston valve" is composed of two discs on a hollow rod; these discs work to and fro in a cylindrical seat; in the interior of this seat three ports are formed, the central port being connected with the steam supply passage, and the two outer ports through suitable passages with the two ends of the cylinder of the engine. When the valve is at one or either end of its stroke, one of the discs will close one end of the cylindrical seat, whilst the other disc will shut off the communication between the central steam port and the outer port at the opposite end of the cylindrical seat, thus leaving this end of the seat, and consequently the outer port formed therein, open to the valve casing, by which the valve seat is surrounded; this casing is connected with the exhaust, and is conveniently cast in one piece with the cylinder of the engine. At one end of the valve's hollow piston rod, is formed a hollow plunger which works in a cylinder formed at one end of the valve casing; the left hand end of this cylinder is closed by a cover which is formed in one piece with the end cover of the cylinder of the engine; the back end of the plunger carries a piston which is of a larger diameter than the other, and works in a corresponding enlargement in the valve cylinder. A constant supply of steam, is admitted to this enlarged part of the cylinder, to act against so much of the piston as projects beyond the plunger; this is effected by admitting steam through the hollow piston rod by small holes, and allowing the steam to pass therefrom through other holes formed through the plunger. The pressure of steam thus acting against the outer ring of the piston will tend to press the piston back against the back end of the cylinder, and so hold the valve over to that end of its stroke, as shown in the illustration. Through the cover of the valve cylinder is a passage leading to the port in the side of the cylinder near its other end. Through this cover is also another passage leading to the exhaust: this passage is fitted with a valve formed with a rod which passes out through a stuffing box in the end cover; this rod is acted on by a spring which holds the valve closed. A tappet rod passes through a stuffing box in the end cover of the engine cylinder; the outer end of this tappet is jointed to the lower end of a lever; the upper arm of this lever bears against the rod of the valve so that when the engine piston at the end of its stroke comes against the tappet the lever may be pressed back and so caused to open the spring valve.

Figure 128, on the next page, shows a longitudinal section of part of an engine similar to that shown by Figure 127, except that the spring valve is opened and closed by a small piston instead of by the tappet rod, and that the small flow of steam is governed by a grooved valve projecting out from the smaller valve. In this arrangement the small or extra piston works in a short cylinder, the inner end of which is, by a passage, open to the port passage leading to the end of the engine cylinder, and the outer end of the valve cylinder, is also by a passage, connected with the port in the side of the engine cylinder. In this arrangement when the engine piston is moving towards the cylinder cover and has passed beyond the side port, then steam will pass through that port to the back of the extra piston and will so open the small valve, thus at once causing the slide valve to be shifted; steam will also immediately pass through the direct passage, whilst that side port will be opened to the exhaust, and thus the small valve will be closed. As soon as the engine piston has passed back again over this side port, steam will be acting upon both sides of the extra piston, and the small valve will be held closed by the pressure of steam acting upon the top of the valve. When the engine piston has travelled back to the opposite end of the engine cylinder and has passed over the other side port, steam will as before described pass through this port, and will act against the whole area of the largest piston and then move the slide valve back; the momentary flow of steam which must then take place is effected through the grooves in the side of the grooved valve; this valve works, as is shown, in a cylindrical recess in the hollow piston, a small hole is formed through the end of this recess so that steam is constantly admitted to the recess from the hollow piston to which as before explained steam is at all times admitted. When the engine piston has again passed back over the other side port, steam will again pass through the port and hold the slide valve. At this time both ends of the small cylinder will be open to the exhaust, and the smaller

FIG. 128.

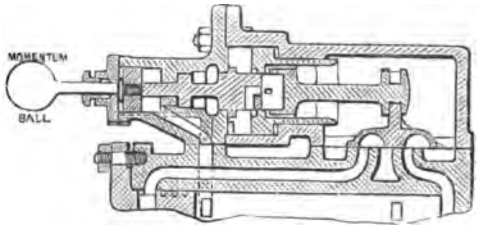


Brown's Self-acting Balance Piston Valve Gear, without the Steel Spring and Tappet Rod, as shown in Fig. 127; patented in the year 1868.

valve will be held closed by the pressure of steam upon it, while the valve will be thus held closed until the engine piston has passed beyond the side port, when the same operation will be repeated.

The illustration shown by Fig. 129, is another arrangement by Mr. Brown in which a slide valve is used to govern the steam and a balanced piston valve is used to work the former; in fact two duties in the place of one as before.

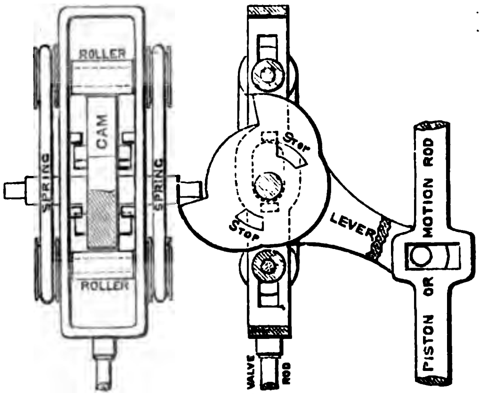
FIG. 129.



Brown's Steam Balance Piston Valve, for working a double-ported Slide Valve; patented in the year 1868.

Just immediately after Mr. Brown brought out his ideas of what valve gear should be, a Mr. Pocock of London brought out his also, as shown by Fig. 130, which is a lever and a cam, worked by the main piston-rod or by any other means; the cam is fixed on a pin that is supported in two slots in the side frames, connected to the valve on each side of the cam: and india-rubber springs keep the top and bottom rollers in the frames, always against the cam, so that by the peculiar form of the cam an unequal motion is imparted to the valve-rod; two stop-lugs on the cam and side frames also regulate the action of the springs.

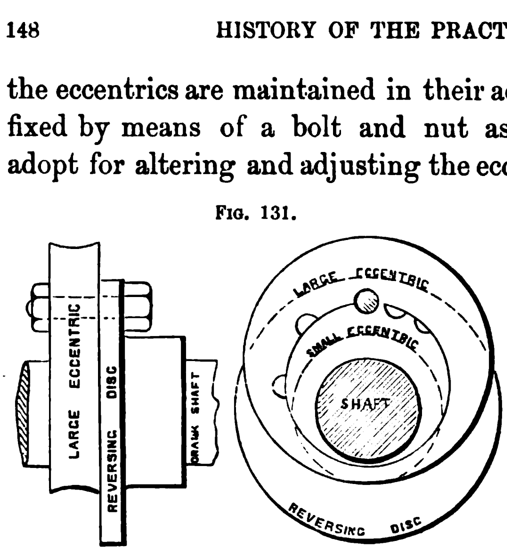
FIG. 130.



Pocock's Lever, Cam, and Spring Valve Gear; patented in the year 1868.

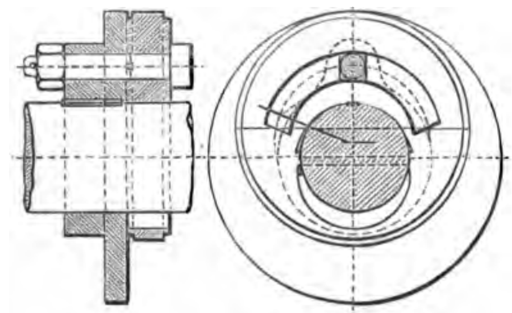
To try to supersede Chapman's ideas for shifting the eccentric, as shown by Fig. 119, on page 136, a Mr. Tasker of Andover patented a method as shown by Fig. 131, on the next page, which is side and elevations of the arrangement of two eccentrics of unequal diameters, the smaller being contained in the larger. These eccentrics are of course loose on the crank shaft, on which is keyed a reversing disc or plate by which the eccentrics are maintained in their adjusted position, as required when fixed by means of a bolt and nut as shown. The mode preferred to adopt for altering and adjusting the eccentrics is as follows:—At various distances on the outer edge of the smaller eccentric several semicircular or other shaped notches are cut, the said distances being determined according as it is required to cut off the steam or to close the port at $\frac{1}{4}$, $\frac{1}{3}$, $\frac{1}{2}$, or any other part of the stroke. On the inner edge of the larger eccentric other correspondingly shaped notches are made at various distances according to the relative size of the two eccentrics. The bore of the larger eccentric is such that the smaller fits it so as to enable the two to be turned on or around the crank shaft independently of each other. In adjusting the eccentric a notch in the smaller one is turned opposite to the corresponding notch in the larger eccentric, and the two eccentrics are held together by the bolt passing through them both and through a hole in the reversing disc.

Fig. 131.



Tasker's Adjustable Eccentrics, for altering the travel of the Slide Valve; to be used as an Expansion Gear; patented in the year 1868.

Fig. 132.



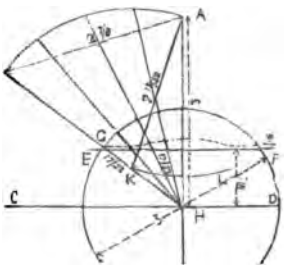
Hartnell's Adjustable Eccentric, for altering the travel of the Slide Valve, with a radial Slot for the bolt; to be used as an Expansion Gear; patented in the year 1868.

Treading on the heels of that arrangement is this shown by Fig. 132, which was introduced by Messrs. Hartnell and Guthrie of Gloucestershire, but has been claimed since by some one else, who states he used it six years ago; but as it is recorded as a patent, and as we have no prejudice in any case, we give the facts just as we find them. This illustration is shown in side sectional and complete end elevations, the reversing disc or plate is here keyed on the shaft as in Fig. 131, and the eccentric is secured to the disc or plate by a bolt and nut as in that case; the eccentric is shown as in mid-gear, but it can be secured in full or any other gear as required by slackening the nut, then turn the eccentric around on the plate, and tighten the nut, so as to hold the eccentric in the settled position, the eccentric in this case is slotted in its bearing on the shaft, thus dispensing with the inner eccentric shown in Fig. 131.

The illustration Fig. 133, is a geometrical diagram of the action of the eccentric shown by Fig. 132, also for determining the radius of the curved slot in the eccentric.

In this case the lap of the valve is $\frac{7}{8}''$, lead in full gear $\frac{1}{16}''$, travel three inches. The radius of the slot $2\frac{17}{32}''$, and its distance $\frac{17}{32}''$ from the centre of the eccentric, were found from practice. The construction of the diagram will be understood by observing that the centre from which is described the curved slot, must always be on the same radial line through the centre H as the centre of the eccentric. It must also be in this case $\frac{17}{32}''$ from the centre of the eccentric and $2\frac{17}{32}''$ from the centre of the bolt. A H, C D are centre lines. C is the centre of the eccentric in full gear. K L is a radius described from the centre A of the bolt. K G is found to measure $\frac{17}{32}''$; and by measuring $\frac{17}{32}''$ from the arc K L along other radial lines, as shown, other positions for the centres of the eccentric will be formed, and their distance from the line E F will be the lead of the valve for those positions of the eccentric. The lead may be made to increase or diminish as the eccentric approaches mid-gear by reducing or increasing the radius A K.

FIG. 133.

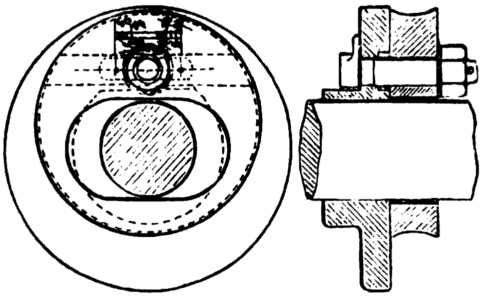


Geometrical diagram of the Adjustable Eccentric shown by Fig. 132.

Another arrangement of adjustable eccentric by Mr. Hartnell is shown on the next page, by Fig. 134, in sectional and complete elevations. In this case the adjustment is effected by *sliding* the eccentric on the shaft instead of turning it partly around, but excepting that, all the details are much as those just described and illustrated.

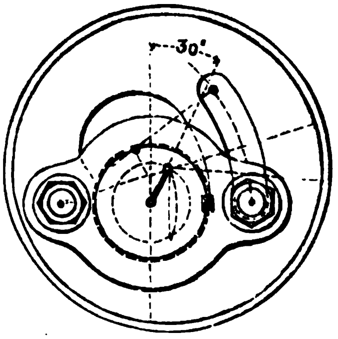
A different method of connection is shown by Fig. 135. This has two bolts and nuts for the adjustment of the eccentric, and the securing disc is of the smallest proportions coincident with strength of material. This has been used in America for several years lately with as much success as any other arrangement of a similar order. Analogous with it is this shown on the next page, by Fig. 136, which although of a slightly different proportion and shape, is practically similar in its workings.

FIG. 134.



Hartnell's Adjustable Eccentric, with a straight Slot for the bolt, for altering the travel of the Slide Valve; to be used as an Expansion Gear; patented in the year 1868.

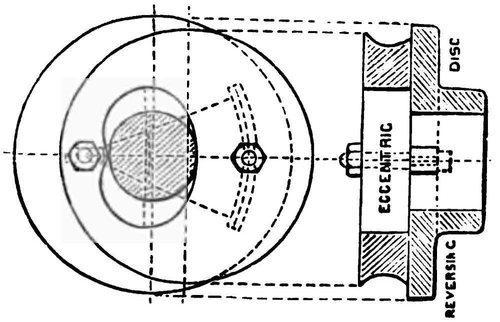
FIG. 135.



Adjustable Eccentric, with curved Slots in the Eccentric, for altering the travel of the Valve; secured with two bolts and nuts; used as an Expansion Gear in the year 1868, and for six years previously.

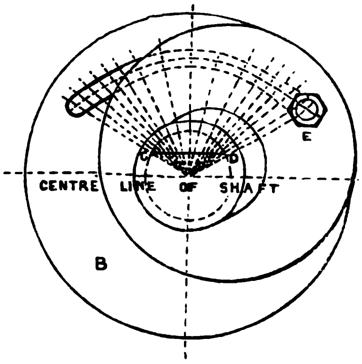
Different from either of the two last examples, but not much so with that shown by Fig. 132, on page 148, is this shown by Fig. 137. Here the eccentric is secured by the bolt and nut E to the disc B, which is keyed on the shaft, as in the other cases, and C D is the line to indicate constant lead, in conjunction with the dotted circle that represents the limit of travel or throw. The setting out of the irregular curve in the securing disc, is thus:—Draw any number of radial lines from the centre of the shaft equidistant through the line C D, and with the distance D E, set off from the line equal lengths, and through the intersections draw the irregular curve as shown, which is the centre of the slot required in the disc; also it must be understood that, the limit of the distance D E is proportionate to the alterations of the grades of expansion required.

Fig. 136.



Messrs. Ruston, Procter and Co.'s Adjustable Eccentric, secured by two bolts and nuts, for regulating the Cut-off of the Steam by the Slide Valve; as used in the year 1868, and also in 1867.

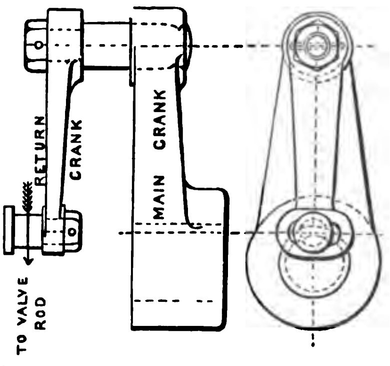
Fig. 137.



Robey's Adjustable Eccentric, with an irregular curve for the bolt, for the regulation of the Cut-off of the Steam by altering the travel of the Slide Valve; as used in the year 1868, and for two years previously.

Of course it is known that the centre of the eccentric revolves around the centre of the shaft when in motion, or as a crank pin: and equally of course a small crank keyed on the main crank pin, and turned towards the centre of the shaft less the half travel of the valve, with a pin in it, will perform all that an eccentric can do; this can be better understood from the illustration Fig. 138, which is side and end elevations of the main and return cranks of an engine without any eccentric; the length of the return crank is less than that of the main crank by the half travel of the valve—or "throw" of the eccentric if it were used—but the same result would be effected if the return crank were longer than the main crank as much as it is now shorter, or the motion pin below the centre of the shaft instead

Fig. 138.



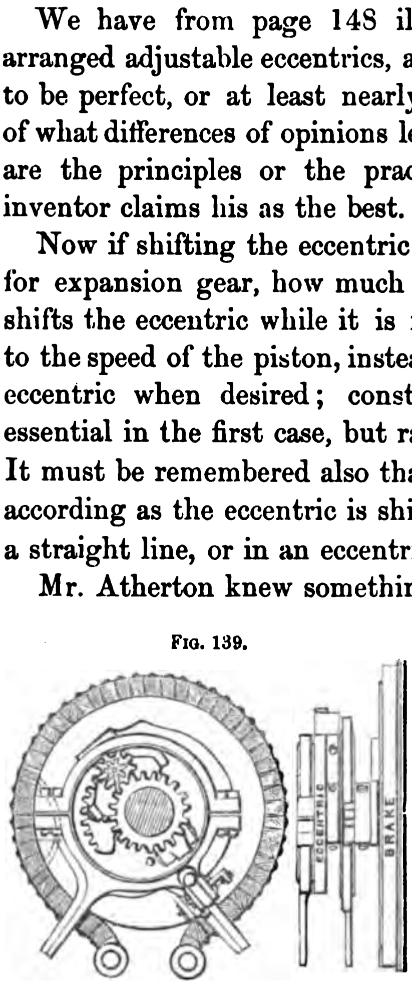
Ordinary Crank-Motion for working the Slide Valve of an Engine; most often used for Donkey Pump Engines during the last fifteen years.

of above it as shown. The slot in the end of the return crank is for the alteration of the grade of expansion or point of cut-off by the slide valve. It is obvious also that this slot can be curved to suit any requisition of working, or indeed of any shape as may be desired.

We have from page 148 illustrated and explained six differently arranged adjustable eccentrics, and as they all are said, by the inventors, to be perfect, or at least nearly so, we have a very conclusive evidence of what differences of opinions lead to, inasmuch that in no two instances are the principles or the practice the same, and yet each maker or inventor claims his as the best.

Now if shifting the eccentric around on the shaft is all that is required for expansion gear, how much better must the arrangement be that shifts the eccentric while it is in motion to the greatest exactitude due to the speed of the piston, instead of stopping the engine to re-adjust the eccentric when desired; constant lead being of course not deemed essential in the first case, but rather a lead proportionate to the speed. It must be remembered also that there is a vast difference in the result according as the eccentric is shifted, that is, whether at right angles in a straight line, or in an eccentric curve, or radially.

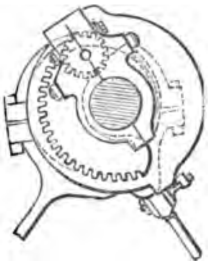
FIG. 139.



Randolph's Adjustable Eccentric, worked by Spur Gearing and a brake; to be used either as an Expansion or Reversing Gear while the engine is in motion; for High-pressure Cylinders; patented in the year 1856.

Mr. Atherton knew something of that circumstance when he patented his adjustable eccentrics in the year 1850, as illustrated on pages 30 and 31, and Messrs. Randolph and Elder, six years after, were equally well informed on this subject; as the illustration Fig. 139, indicates. The arrangement of this gear is, that on the crank shaft there is a loose toothed wheel, also to its side is secured a friction pulley and brake, and a certain portion of the inside of the rim of the eccentric is formed with teeth, that gear with a pinion that is secured to the eccentric, and situated between the teeth and those on the loose wheel; this pinion therefore will shift the eccentric either to the right or left when the brake is tightened, and thus alter the grade of expansion, and also reverse or stop the engines as required.

FIG. 140.

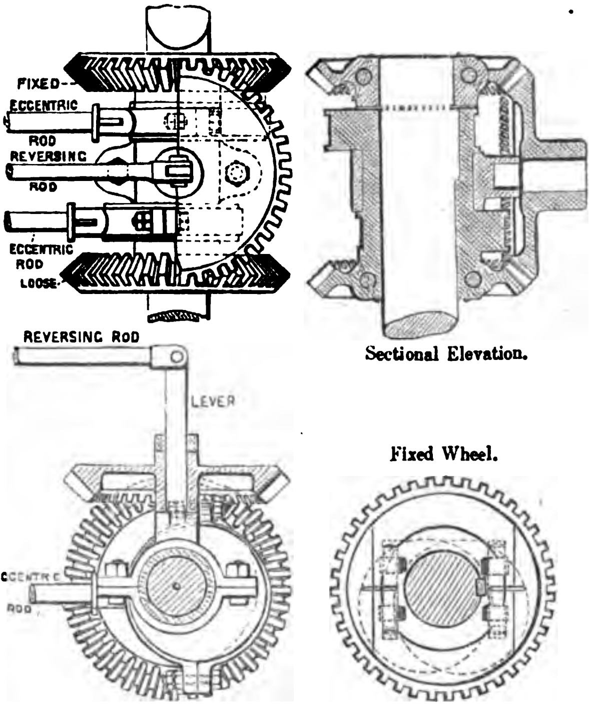


Randolph's Adjustable Eccentric, for Low-pressure Cylinders; patented in the year 1856.

In the case of compound engines there would be two arrangements—that just described being for the high-pressure cylinder—and this shown by Fig. 140, being for the low pressure: it may be stated also, that the former has a short arc or a quadrant throw, while the latter has a half circle or a semicircular throw, due of course to the laps of the two valves, the respective pinions being made to correspond.

A very ingenious method for shifting the eccentric while the engine is in motion also, is shown by Fig. 141, on the next page; this was invented by Messrs. Bruckshaw and Cornes of London, in the year 1867, and illustrates what means were resorted to, to make an expansion and revolving gear different from any other if possible. Spur gearing it will be remembered has been much used, and screws and nuts, and bevel gearing also; but mitre gearing has not been so often applied. The arrangement of this gear is as follows:—A mitre wheel is fixed or keyed on the crank shaft, opposite to which is another wheel loose on the shaft; this wheel has formed with it a tube, together with the eccentric or eccentrics; between them is a loose collar in halves connected together by bolts and nuts, on the upper half is a boss into which a lever is attached, and on the lever is keyed a third mitre wheel—shown in section in the end view and half only in the plan—that gears with the other wheels. Now obviously when the shaft is revolving the fixed wheel will, by the intermediated wheel, drive around the loose wheel, the tube, and likewise the eccentrics; but if the lever is moved to cause an exceptional motion to the loose wheel, then the eccentrics are shifted independently of the shaft, and thus the slide valves are similarly affected. When the lever is in the position shown, the engine is stopped, and when on either of the extreme angular positions it is in motion one way or the other; the plan and section shows two eccentrics, which can be used for two engines, or for two valves of one engine as may be required.

FIG. 141.



Sectional Elevation.

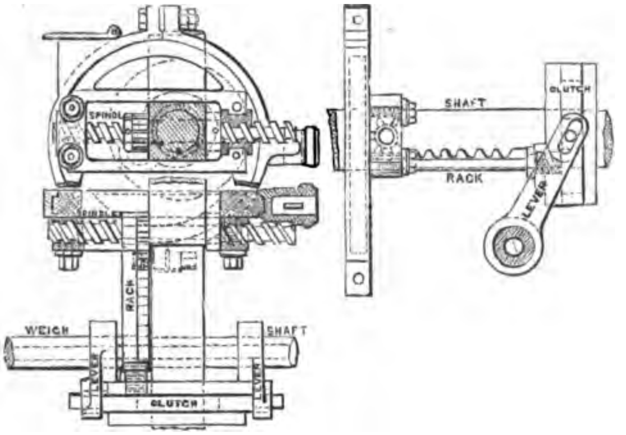
Fixed Wheel.

Cornes' Adjustable Eccentrics, shifted by Mitre Gearing; to be used either as an Expansion or Reversing Gear; exhibited at the Paris Exhibition of 1867.

If a combination of mechanical contrivances is an achievement in this matter, the arrangement shown by Fig. 142 must have cost some trouble, for here we have the screw, the rack and pinion, the clutch and lever, all brought together to perform one purpose—*i.e.*, shift the eccentric at right angles to the shaft. This arrangement is shown in three views, and the following description will make them to be readily understood.

It will be seen by the end view that the crank shaft is made of square section at the part where the eccentric is, and that the long slot in the eccentric is fitted to this square portion so that it can slide across the shaft from the position of full gear forward to that of full gear backward, or remain in any intervening position, so as to vary the cut-off by shortening the length of the stroke of the slide valve. The traversing motion is effected as follows:—Through the square part of the crank shaft a screwed spindle is carried that is free to rotate and works in two brass nuts, fixed one at each end of the eccentric slot so that as the spindle rotates the eccentric traverses. A pinion is fixed on the screwed spindle close to the shaft which gears into a rack connected to a sliding collar on the shaft, and is moved along it by a pair of arms or levers fixed on a weigh shaft to which a hand lever is attached. It will be understood then, that when the rack is moved in a direction parallel with the crank shaft, rotatory motion is given through the pinion to the screwed spindle, and thus the required traverse of the eccentric is accomplished.

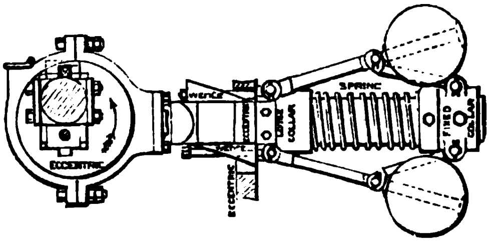
FIG. 142.



Turner's Adjustable Eccentric, worked by a Screw, Rack, and Pinion, with Levers and Clutch; applied in the year 1868.

To the present it will be remembered that all the adjustable eccentrics we have illustrated are either shifted by hand power when stationary, or by gear when in motion; but in both cases actuated by the hand as a separate means from the motion of the engine; Messrs. Robey of Lincoln, however, have dismissed the hand as a motive power, and by a ball governor, horizontally situated, actuate the eccentric with a combination of Dodd's Wedge Motion—which was invented as far back as the year 1839, as illustrated on page 17.—The illustration Fig. 143 shows the application of this gear to an engine with one slide valve. The eccentric is formed with a rectangular opening in it, which fits on a square portion on the crank shaft—as in the preceding example;—it is retained in any position at right angles to the crank, by two wedges of a parallel form which traverse forward and backward on the shaft within the eccentric, and thus its throw is altered. The mechanical arrangement is thus:—On the right hand of the governor there is a collar that is fixed on the shaft, opposite to which is a loose collar that is connected to the wedges. Obviously then, when the balls of the governor recede by their centrifugal action, the wedges are pulled by the rods through the eccentric, and it slides upward, or in the direction of the arrow in the end view; thus the travel of the valve is likewise affected and the cut-off of the steam earlier than before. We may observe also that by reversing the position of the wedges the direction of the crank's movement will be similarly affected. The motion of the governor, therefore, when at its highest speed, reduces the travel of the valve, and when working at the slowest, enlarges it; of course in either case it is limited to the throws of the eccentric or rather the angle of the wedges. This gear can be used also in combination with an ordinary eccentric motion for separate cut-off and exhaust valves.

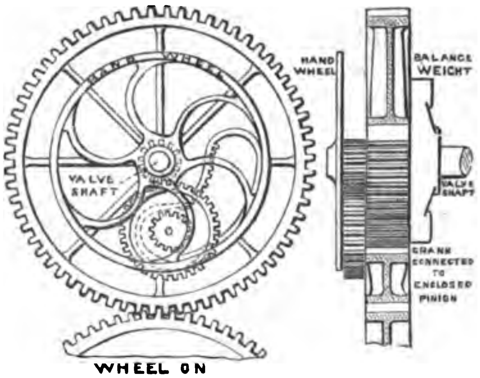
FIG. 143.



Robey's Adjustable Eccentric, worked by a Ball Governor and "Dodd's Wedge Motion;" applied in the year 1868.

Spur gearing has often been used to shift the eccentric around the shaft, as also has mitre gearing; but in nearly all cases an eccentric has been deemed imperative. Our French neighbours, however, have thought fit to copy Messrs. Maudslay's method to the extent of the use of cranks in the place of the eccentrics, when the slide valves are on the top of the cylinders and the motion shaft in front opposite the valve casings. The English firm, it will be remembered, use spur gearing also for the valve motion, as illustrated by Fig. 80 on page 99, and the cranks and shaft of course being formed together, are similarly shifted. The French valve gear is shown by Fig. 144, and its explanation is best expressed by our critique of the French Exhibition in the "Engineer" of August 23rd, 1867, thus:—"The valve shaft is driven by a pair of spur wheels of equal diameter, one being on that shaft, and the other on the main shaft, at the forward ends. Reversing, stopping, and starting are effected by tooth gearing on the end of the valve shaft; outside the spur wheel is a pinion, and beyond this a hand wheel with a rim, with a 'jam wheel;' in the body of the spur wheel is a space and a quadrant rack, the radii of which are taken from the centre of the shaft; in gear with the rack is a pinion, and on its shaft is a second pinion of a larger diameter than the first, which gears with the pinion on the valve shaft. Now on motion being given to the hand wheel, independently of the engines, the valve shaft will be turned around independently also, and thus the valves are stopped or shifted either way as required, but with the consequence that if the hand wheel cannot be instantaneously released by the 'jam-wheel' outside it, the engineer will be hurled away from his duty by the centrifugal force of the rim."

FIG. 144.

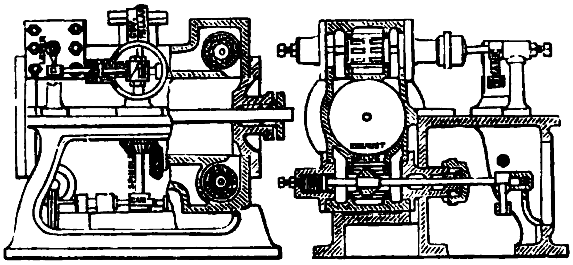


French "Whirligig" Valve Gear, of the Marine Engines that gained the prize at the French Exhibition of 1867.

A very singular example of valves and gearing was patented in this year, 1868, by Mr. Newton of London, for a Mr. Loomis of New York, which consisted of the adoption of hollow perforated cylindrical conical valves fitted into perforated shells that are secured in the steam chest. The valves are oscillated by means of a cam fitted on the spindle of the governor, and when so moved, their perforations come in line with those of the hollow seats, and thus let the steam into the cylinder. When the projecting part of the cam does not act upon the valve connections the valves will be closed. The construction and arrangement of this cam and gear for operating the valves in the steam chest is that the cam is of cylindrical or conical form with a spiral projection, and is fitted on the spindle to be adjustable to the up-and-down movable stem, which is raised and lowered by the action of the governor balls. Levers which are attached to cranks projecting from the valve rods are with their ends held against the periphery of this cam, and when the spiral projection is brought between them and the axis of the cam they are pushed off so as to open the valves; springs or other equivalent devices throw them back again to close the valves as soon as the projection has passed. The projection of the cam being spiral on one edge and not on the other is consequently wider on one end than on the other; the opening of the valves is therefore regulated by the height of the governor stem, and also by its direct adjustment around the governor spindle.

This arrangement was of course patented to elude the "Corliss" arrangement, and to show how it was accomplished we have illustrated it by Fig. 145, in side and sectional elevations; it will be seen that the main agent, the cam, can be adjusted up and down on the spindle by setting the securing nuts, and its position is also regulated by means of the governor's action, which draws the stem and its appliances up and down as the levers are being spread or contracted in position. In each steam chest is formed a somewhat conical perforated shell which forms the seat for a conical hollow perforated valve that is mounted on a shaft, as described. The shaft has its bearings in the ends of the steam chest or in other suitable supports, and has a crank formed on it, as represented. To the end of the crank is fixed a bar which is by means of a spring held with its end against the cam or cylinder, as shown in the side elevation. As the spindle is being revolved the cam is once during every revolution brought between the end of each lever and the ring, and pushes the crank away so as to turn the valve in its seat, thereby opening the port. When the lever is not held out by the cam, the ports are closed. Now it is evident that the lower the cam is situated the longer will the ports remain open during one revolution of the governor, and the higher it is the quicker will they be closed, owing to the tapering form of the cam. If the engine goes too fast the balls will spread and raise the cam, causing less steam to enter the cylinder until the required equilibrium has again been obtained. The supply valve can be ground into the seat; one end of its shaft rests against a spring to allow expansion and contraction of the parts. Valves of similar construction are also used for the exhaust. They are there confined within seats as shown, and are operated by means of a full stroke cam mounted on the rotary spindle.

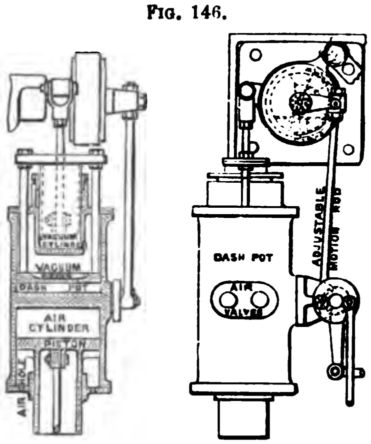
FIG. 145.



Loomis' Oscillating Cylindrical Perforated Valves, worked by Mitre Gearing, Levers, Cams, and Springs, controlled by a suitable Ball Governor; patented in the year 1868.

Early in this year Mr. Spencer came forward again with his notions of improved "Corliss" valve gear, in connection with a new "dash-pot," which had no springs, but solely depended on the atmospheric pressure and its exhaustion, or a vacuum, for the sudden motion of the pistons connected to the steam valves, as shown in sectional and complete elevations by Fig. 146, and the advantage gained is that the apparatus is cheaper than his other and equally as efficient.

FIG. 146.



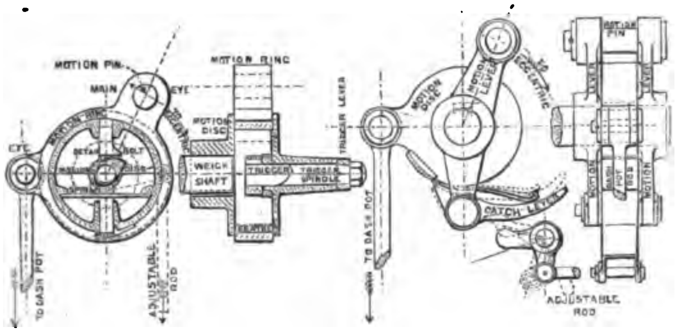
Spencer's Vacuum "Dash-pot" and Gear, for closing "Corliss" or other Equilibrium Valves; patented in the year 1868.

The arrangement consists of plungers and pistons working in corresponding cylinders, the effect of which is, mainly, the closing of the supply steam valves by suitable gear, by means of a piston working air-tight in a cylinder and connected to a lever on the steam valve rod, or to a lever on a weigh shaft, that gives motion to the steam valve rod, while the piston is drawn out by the opening of the steam port, and thus forms a partial vacuum on the inner side of the piston, and by the pressure of the atmosphere on the outside of the piston it closes the steam port when the detent releases the valve. By this arrangement the movement required to open the steam valve also gives motion to the vacuum piston and creates the vacuum, and the usual dash pot or air cushion can be formed by the vacuum piston itself or by a separate cylinder and piston as preferred.

Inlet and outlet air valves are fitted to the vacuum cylinder to regulate the amount of vacuum required, and in cases where no separate dash pot is used, also to regulate the amount of cushioning required.

The improved valve gear is shown by Fig. 147, on the next page; it is of two arrangements: the first on the left hand, in sectional views, consists of a motion ring with two eyes formed therewith, the main eye being in connection with the eccentric, and the other with the dash pot; the motion disc, keyed on the weigh shaft, imparts motion to the admission or cut-off valve, and the ring and disc are connected intermittently by means of the "detent" bolt and trigger; the latter being kept stationary when required by an adjustable rod. The movement of the ring indicated by the arrow lifts the detent-bolt clear off the trigger, and thus releases the motion disc, also thereby permits it and the valve to be actuated by the dash-pot piston and rods.

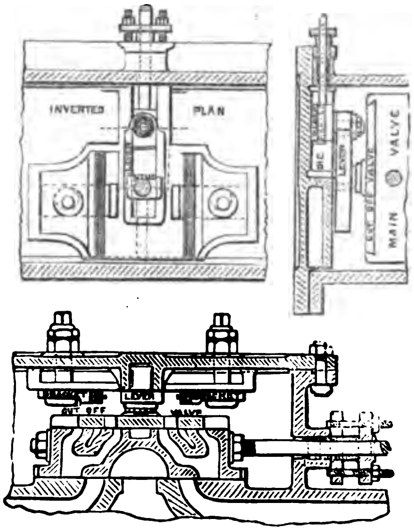
FIG. 147.



Spencer's "Radial Escapement Gear," for working "Corliss" and Equilibrium Valves, patented in the year 1868.

The second arrangement of gear is shown in two complete views on the right hand, in which levers and a spring perform the requisitions of the detent-bolt trigger and ring.

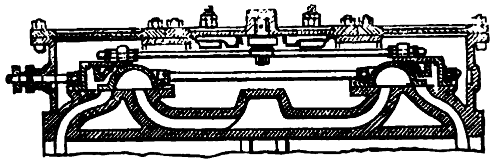
FIG. 148.



Shelmerdine's Main and Cut-off Valves, worked and regulated by an Eccentric and Ball Governor, patented in the year 1868.

Within one month after Mr. Spencer had petitioned for his patent just described, Mr. Shelmerdine, with two friends of his, the trio being at Manchester, began to patent the arrangement of valves as shown by Fig. 148, which is an arrangement of main and cut-off valves regulated by suitable means at *right angles* with each other; the working of the top valve being dependent on the frictional contact of the two faces, due to the pressure of the steam acting on the top surface. The main valve, which is worked by an eccentric, has two ports in it at each end, through which steam is admitted, and a face port also at each end through which the steam passes to the ports of the cylinder. The cut-off valve is fitted in dovetail slides on the back of the main valve, as shown in the end view, and has two ports in it to correspond with the inner ports in the back of the main valve. There is a stud fixed in the back of the cut-off valve, and a die is fitted to swivel upon the stud, which die fits into a parallel slot in a lever, therefore the lever can slide to and fro on the die. The fulcrum of the lever is upon a stud fixed in a block that can slide to and fro in guides formed in the lid of the valve chest, and this block has a rod screwed in it which passes through a stuffing box to the exterior of the valve chest, this rod being connected with the ordinary ball governor of the engine by rods and levers or other suitable means, by which, when the speed of the engine increases, the rod will be pushed inwards, and *vice versâ* when the speed of the engine decreases. The end of the lever moves between parallel ribs or stops which stop its movement. These ribs are formed by two brackets fitted in parts projecting from the steam chest lid, so that they can be slid to and from each other, and they are secured by bolts, one for each stop. Each bolt has a small eccentric formed upon it which enters a suitable slot—shown in dotted line in the plan—in the stop, so that by rotating the bolt, the position of the stop can be adjusted, and then the bolt can be secured by the lock nuts. Upon each stop a series of thin plates are loosely secured one against the other by two screws—to deaden the shock or blow which the end of the lever gives upon the stop.

Fig. 149.

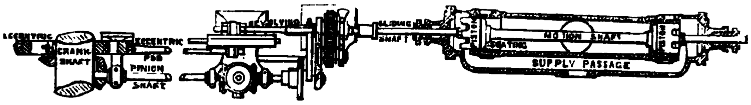


Shelmerdine's Main and Cut-off Valves for Long Cylinders, patented in 1868.

The illustration shown by Fig. 149 is an arrangement of double main and cut-off valves, for long cylinders, connected by rods, but worked by the same methods as in the previous example.

Just after this period another Mr. Holt—for Mr. Shelmerdine had one of that name with him—joined Mr. Galloway in inventing and patenting an arrangement of sliding and revolving gear for working piston valves, as illustrated by Fig. 150. The ports of one valve seat are opposite the intermediate or closed ports of the other valve seat, whilst the spaces or ports of one valve are opposite to those of the other. The pistons are secured on the shaft, so as to be capable of rotation with that shaft, when rotary motion is imparted to it. Traversing motion is imparted to the shaft, and consequently to the valves, by means of the eccentric on the crank shaft, or it may be by other suitable means through the connecting rod, the other end of which embraces a stud, which is capable of sliding in a slot formed for it in the stationary guide, and is formed to receive the outer end of the rod, which at that part is provided with collars and set nuts, so that it may be moved endways with any to-and-fro motion of the stud, and yet be free to revolve therein. In order that rotary motion may be given to the valves, the shaft is formed into sexagonal or other suitable form, to slide endways through a corresponding shape in the boss of the tooth wheel, and according to the arrangement shown, this progressive rotary motion, at the times and to the extent desired, is first obtained from the bevel toothed wheel on the crank shaft, the teeth of which gear into the teeth of the bevel tooth wheel fixed on one end of the pinion shaft, which is supported so as to be capable of revolving in stationary bearings, and has fixed on its other end another bevel pinion, which by means of the horizontal bevel pinion is capable of giving motion to the fifth bevel pinion fixed on one end of the countershaft, which latter is also supported with capabilities of revolving in stationary bearings, and has connected to it by a spring clutch-connection a face plate, that has a stud projecting from it in position to act upon the teeth of a star wheel, as shown in detail by Fig. 151, and the rotation of the face

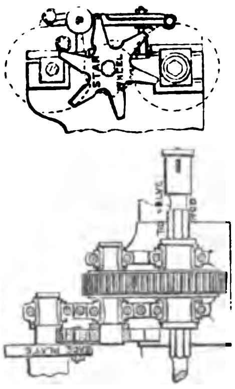
FIG. 150.



Galloway's Revolving and Sliding Motion, Valves, and Gear, for working the Piston Valves, as shown in section, patented in the year 1868.

plate imparts, "step-by-step," rotary motion to the star wheel. This star wheel is secured to one end of a shaft, which is supported in proper bearings, and has keyed upon it a spur pinion, the teeth of which take into the teeth of a spur wheel; and thus rotary motion is communicated to the valves. But that the extent of this motion may be controlled by the governor, the horizontal bevel pinion is arranged to revolve on an arm, which is formed with lugs to turn in suitable bearings coincident with the centres of the shafts, while the outer end of this arm is by a pin joint, and a suitable connecting rod linked to the governor to be operated by it, so that as the governor rises or falls the other end of the arm is actuated in one or the other direction, turning the bevel pinions partially round, thereby altering the relative movements of the spur pinions, and thus causing the stud in the plate to act sooner or later on a tooth of the star wheel, varying the cut-off effected by the valves; there are stops, also, which simply hold the star wheel in position.

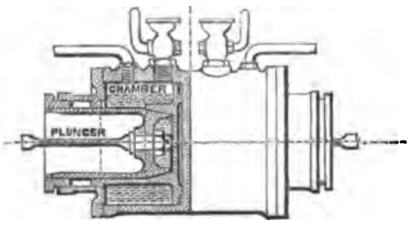
FIG. 151.



Details of Galloway's Valve Gear, shown complete by Fig. 150.

At the end of this year, 1868, Mr. Inglis patented two new dash-pots for closing the "Corliss" valves of compound or any other engines, one of them being shown by Fig. 152. It will be understood that the two portions, sectional and complete, are duplicate, to serve for the two opposite steam valves of one cylinder, and one set of the parts is shown in section. A plunger is arranged to work through a stuffing box into a cylinder or chamber, which is in communication with the condenser by a pipe, so that the atmospheric pressure constantly tends to force the plunger inwards. The chamber is filled or partly filled with oil or other suitable liquid, and the

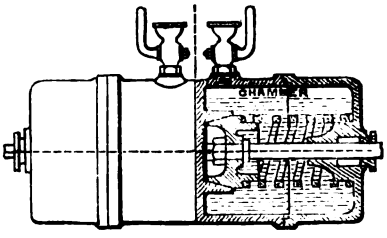
FIG. 152.



Inglis' "Dash-pots," in which the Plungers are actuated by the Atmosphere and Oil, patented in the year 1868.

bottom of the plunger is made conical to fit a conical seat formed for it in the inner end of the chamber. The plunger is connected to the valve gear by the spindle, so as to be drawn outwards when the valve is opened, and on the gear being released it moves the valve back, its own momentum being gradually checked close to the end of its traverse inwards by its having to displace the oil from the seat. Instead of the plunger or its equivalent being moved inwards by atmospheric or other equivalent pressure, the necessary pressure for that action may be applied by a metallic or other spring, the oil or other liquid being in all cases retained to prevent violent concussion at the end of the inward movement.

Fig. 153.

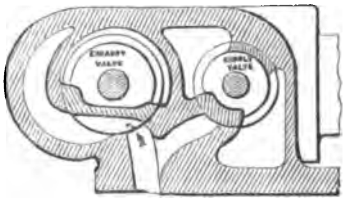


Inglis' "Dash-pots," in which the Plungers are actuated by Steel Springs and Oil, patented in the year 1868.

Figure 153 is a sectional elevation of the other dash-pot, which is a modification embodying a convenient mode of applying a metallic spring, a spiral steel spring being placed between the plunger and the cover of the chamber, and in a state of compression sufficient for forcing the plunger against its seat.

The next year, 1869, was rather rich in new valve gears, and the "Corliss" valves seem to have met with much attention then, for their practical application was considered novel, and of course therefore interesting; but with the use of those valves the various inventors introduced new gear, which practically nearly obviated the original kind, and also that which immediately followed it, without the advantages they possessed. What seemed to be the prevailing fashion was old "Corliss" valves with new gear for working them. As an example Fig. 154 is introduced, which is an illustration of Messrs. Holcroft and Dack's "Corliss" valves as arranged and patented by them on the 1st of April in the

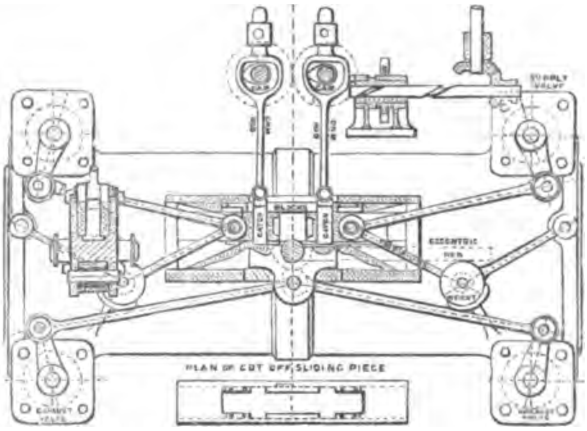
Fig. 154.



Holcroft's "Corliss" Valves for the Supply and Exhaustion of the Steam, situated together; patented in the year 1869.

year 1869, and Fig. 155 represents their gear when those valves are arranged separately or as usual. The main feature in this gear is that there are no dash-pots, but cam-motion catches and weights perform their use.

FIG. 155.



Holcroft's Valve Gear, with Catch-pins, Cam-motion Weights, and Eccentric-gear, for working "Corliss" Valves; patented in the year 1869.

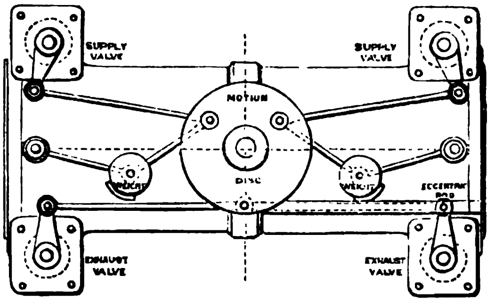
This arrangement is, that at the centre of the length of the cylinder there is a slide or sliding-piece used for the actuation of the cut-off and exhaust valves, which are attached by rods without the usual clips and toe-lever gear. This slide is worked by an eccentric rod in the general way, and is fitted with flanges, shown by the end section, between which sliding blocks fit; these sliding blocks are connected to or disconnected from the slide by means of catches, which are raised by the cams above and drop by their own weight or by a spring. The sliding blocks are connected to the supply valves by links, and they are also connected to jointed links fitted with weights, which form the joints: the slide is connected to the exhaust valves by links also.

Above the slide are the cams; one of the cams is provided with a spiral key fitting in a spiral groove in one of the shafts, as shown, which is driven by mitre wheels, one of which is actuated by the engine. The end of the grooved shaft is connected to the governor either directly or by a hydraulic cylinder. The two shafts are driven by spur-gearing.

The method of operating this valve-gear is as follows:—So long as the engine is at work the eccentric rod moves the slide to and fro, and the links work the exhaust valves as usual. When the catches are down, as shown, the sliding blocks are also carried to and fro to work the valves, but as soon as the cam has lifted the catch, the sliding block is instantly brought back by the falling of the weight, which drops into a cup cast with the cylinder and lined with some soft material. The time at which the cam lifts the catch, is regulated according to the speed of the engine, by the governor which moves the shaft endwise, and in so moving, that cam is turned partly round, and thus varies the time of releasing the catch. After the catch has been raised it drops on to the side plates and is held up by them until the sliding block returns to its former position, and allows the catch to drop again into the position shown, and the operation is repeated.

Figure 156 represents another arrangement of gear. In this case also it is applied to a "Corliss" engine without dash-pots, but with the ordinary wrist plate. It is obvious that by the means now shown and that described, the force required to lift the weight or to compress a spring, as in the usual mode of closing the valves, is applied direct to the sliding blocks or wrist plate, instead of it passing through the spindles of the valves as in ordinary examples.

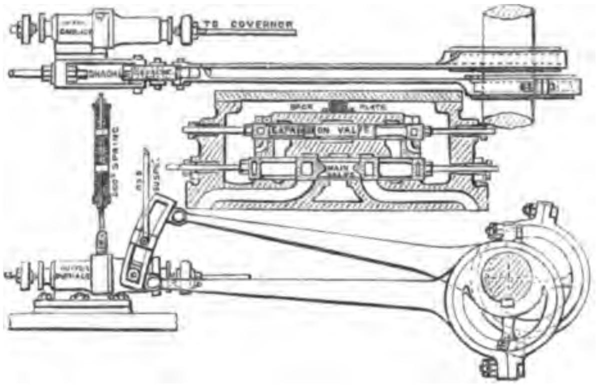
Fig. 156.



Holcroft's Arrangement of "Corliss" Valve Gear to obviate the use of Dash-pots, but use Weights in their place; patented in the year 1869.

Mr. Holcroft and his friend, however, were not content with what they did, as has been stated, but schemed an arrangement of slide valves, and link-motion to work them, as illustrated by Fig. 157. It will be seen that there are two valves, the main valve working under a block valve or frame above, within which works the cut-off or expansion valves, so that there are two back plates for the valves to work against.

FIG. 157.

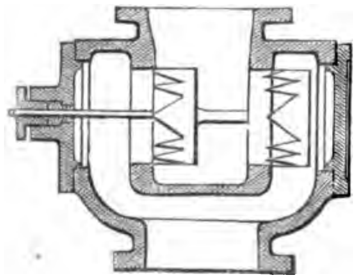


Holcroft's Back-plate, Equilibrium, Expansion, and Main Slide Valves, worked by the Link Motion and regulated by a Governor; patented in the year 1859.

The link-motion is the usual kind, but is in connection with an arrangement of springs to close the cut-off valve quickly as well as to be regulated by the governor by a differential stop gear, which is connected by right and left-hand screwed rods to the buffer carriage and the shackle joint.

The governor spring-gear is rather peculiar, it being two spiral springs at the same angle, having between them a third spring at an opposite angle, by which means when the governor rod is raised the top and bottom springs are compressed, and their rod being in connection with a rack in gear with the buffer, the cut-off valve closes instantly when the release occurs.

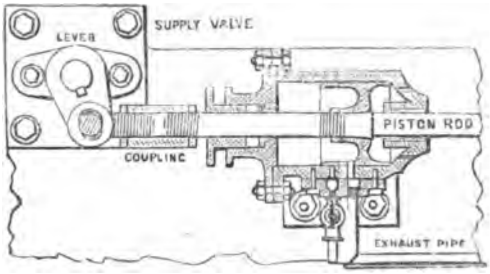
FIG. 158.



Holcroft's Zigzag Cut-off Valves; proposed in the year 1869.

Perhaps the most sensible proposal in all this apparatus is the cut-off valve shown by Fig. 158, which although funny in appearance is not without the advantage of simplicity.

FIG 159.



Rose's Steam "Dash-pot" and Gear for Closing "Corliss Valves," patented in the year 1869.

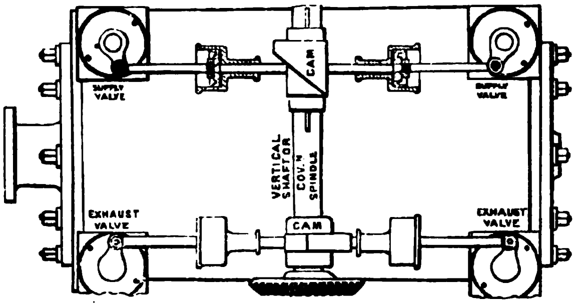
But Mr. Holcroft was not alone in the field of fame for the invention of Corliss Valve Gear, however; because in the same month Mr. Rose of Lancaster patented an arrangement of dash-pot gear, as shown by Fig. 159, by which it will be seen that on the end of the valve rod a lever is keyed, and to it is attached a screw rod, fitting in a socket. This socket, being screwed internally right and left-handed, and at the latter part is fitted with another rod in connection with the piston of the "dash-pot," so that by turning it around in either direction, the connection between the lever and the piston can be lengthened or shortened as required. The piston rod passes through a stuffing box at the left-hand end of the dash-pot cylinder, and through a bush at the other. The rod has a broad piston secured on it, and in this piston there is a small port which is held opposite, or over, another port in the casing or cylinder at the termination of each sudden movement of the piston, thus allowing the steam in the casing to exhaust through the pipe shown. When the piston makes its slow forward movement, the exhaust port is covered, and the next port is uncovered, through which steam enters that may be brought by another pipe, fitted with a stop-plug valve as shown. The pressure of the steam gives the sudden return movement to the piston when the valve-rod is released, by which movement the steam port is covered, and the exhaust port is uncovered at the end of the movement. That end of the cylinder without the stuffing box is termed the dash-pot end, and air is allowed to enter through one or more small holes during the slow movement of the piston, to act as a cushion or buffer to prevent percussion or shock at the end of the return sudden movement of the piston, the air which can escape through the small hole or holes checking the blow.

This patent contained also an arrangement of gear for working Corliss Valves, the main feature of which is the action of a cam for each set of valves driven by mitre gearing.

Now if we turn to page 159, there is represented by Fig. 145 an arrangement of valve-gear by a Mr. Loomis, precisely as Mr. Rose proposes as his invention; which shows how near some inventors often follow the steps of others, although they may be guiltless of knowing that fact, or even intending it.

Mr. Rose's gear is represented by Fig. 160, and is easily understood from that illustration to be as follows:—To the lever upon each oscillating valve rod one end of a piston rod is jointed, and the other end passes through and slides freely in a guide part projecting from the dash-pot casing that is secured to the steam engine cylinder. The piston on the rod fitting the dash-pot cylinder acts as a buffer in the usual manner. The dash-pot, piston, and rods for the supply valves can be made in two parts, connected by a right and left-handed screw coupling as shown previously, to allow for adjustment.

FIG. 160.

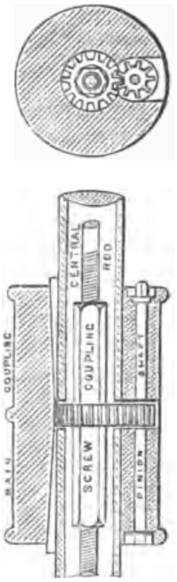


Rose's Vertical Cam Motion Gear, for working "Corliss" Valves, patented in the year 1869.

The motion gear is thus: midway of the length of the steam engine cylinder a vertical shaft is arranged in suitable bearings, and this shaft is rotated by bevel wheels, and a horizontal shaft not shown, driven by the crank shaft of the engine, the vertical shaft rotating at the same speed as the crank shaft.

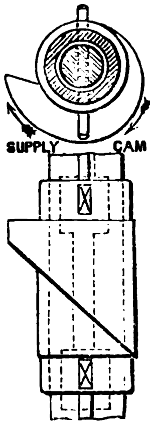
The vertical shaft is hollow, and is formed in two parts connected together by a main coupling, as shown by Fig. 161. The upper end of the shaft carries an ordinary governor, to the sliding boss of which a central rod is secured by a cotter passing through a slot in the sliding boss, the hollow shaft, and the central rod. This rod is in two parts, connected by a long right and left-handed screw coupling, as also shown by Fig. 161, the exterior of this coupling is formed hexagonal, or like a screw nut, so as to fit and slide freely through a corresponding hole in a spur wheel arranged in the main coupling between the two ends of the vertical shaft. This wheel gears with a pinion on another vertical shaft, having bearings in the main coupling, which shaft can be rotated by means of a square end, and a suitable key to adjust the length of the central rod. The lower end of the rod is connected by means of a cotter passing through it and through a slot in the hollow shaft, with a cam of peculiar shape, which can, while rotating, be slid up and down by the governor. The most elevated part of the cam is undercut, as shown in detail by Fig. 162, so as to be clear of the part acted upon when it is suddenly forced back by the valve spring; this cam acts upon the dash-pot piston rod of the supply valves at each revolution, first on one and then the other, so that by varying the position of the sliding cam, the time of cutting off the steam from the cylinder is regulated, and this is done self-acting by the arrangement described. When the speed of the engine increases above that fixed upon, the governor will slide the cam upwards, and this will release the dash-pot piston rod sooner, and allow the valve spring to shut the valve, and *vice versâ*, when the speed of the engine decreases.

FIG. 161.



Rose's Adjustable Spur Gearing Coupling for the Motion-shaft that works the arrangement of Corliss Valves and Gear, as shown by Fig 160. Patented in the year 1869.

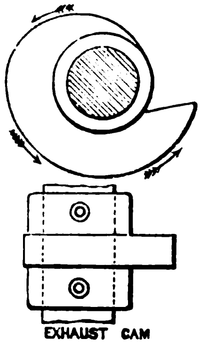
FIG. 162.



Rose's Cam for working the Supply Valves of Corliss Engines, patented in the year 1869.

Other arrangements of mechanism may be employed to connect the governor with the sliding cam, and the governor may be placed in any other convenient position; for example, the cam may be slid to and fro on the shaft by a clutch fork arrangement, or any other convenient means, and for steam engines having vertical cylinders the regulation of the cam's position may be made by a bell-crank clutch lever, and a rod with adjustable screw coupling connected with the governor. The exhaust valves are arranged and actuated like the supply valves, except that the cam, as shown by Fig. 163, is *fixed* upon the vertical shaft, and it is formed to shut the valve slowly and to allow the spiral spring to open it suddenly at the end of the stroke.

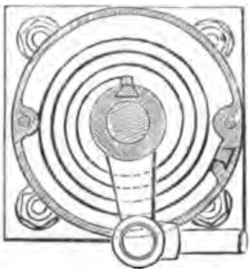
Fig. 163



Rose's Cam for working the Exhaust Valves of Corliss Engines, patented in the year 1869.

The "spiral valve spring" alluded to is shown by Fig. 164, which arrangement is merely that the inner end of the spring is fixed to a key or plug, secured in the boss of the valve, and the outer end to a key or plug fixed in the casing of the valve; and thus the inner end moves while the outer end is fixed, and the uncoiling action of the spring imparts a sudden motion to the valve as required.

Fig. 164.

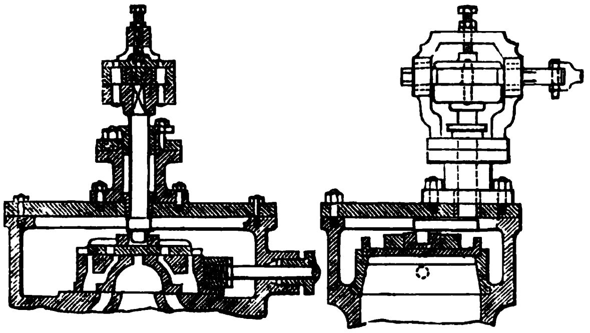


Rose's Coiled Spring, attached to a Corliss Valve and Casing, so as to close the valve when the spindle is released; patented in the year 1869.

It will have been noticed that on page 161, by Fig. 148 is illustrated an arrangement of valves and gear, in which the cut-off valve receives its motion from a lever, the rod of which is worked by the ball governor, and we again illustrate a similar arrangement as illustrated by Fig. 165, as patented by Mr. Cuthell, and constructed by Mr. Cowan of Nottingham.

The main slide valve is constructed as shown in section, and it is fitted with a cut-off plate, which slides freely upon the back of it. The motion of the cut-off plate is controlled by its being connected to the lever formed at the lower end of a rod that passes through a stuffing box on the cover of the valve chest. On the end of this rod

FIG. 165.

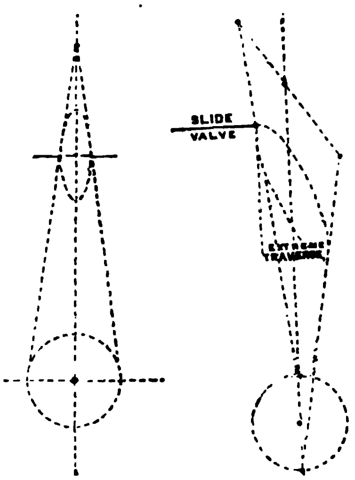


Cuthell's Patent Main and Cut-off Valves, regulated by an ordinary Ball Governor, constructed in the year 1869.

is fixed a disc plate, fitted with studs with swivel blocks, these latter being provided with brass liners, between which the tapered bar, actuated by the governor, works. When the engine is in motion the slide valve tends to carry the cut-off plate with it, and the ports in the slide valve and plate are so arranged that the cut-off can be effected by stopping the motion of the plate before the slide has reached the end of its stroke. The point of the stroke at which this stoppage of the movement of the cut-off plate, and the consequent cut-off of steam, takes place, is regulated by the action of the governor, which inserts or withdraws the tapered bar between the liners of the swivel blocks, and consequently limits or increases the period of rotation of the lever rod, and so regulates the cut-off to the power required. This valve is not arranged to cut off the steam beyond one-third of the stroke of the engine cylinder piston; but three other examples, by three firms, of a similar arrangement are shown on Plate 65.

Ten years previously Mr. Hackworth of Darlington patented a very peculiar arrangement of valve gear, and improved it step by step up to this date, 1869, and the principle of this latest method is that—there is one eccentric for the slide valve of each cylinder, having a rod whose extreme end moves in a straight line. At one-third from the extreme end of the eccentric rod the valve rod is attached, the point of attachment forming, in one revolution of the engine, an elliptic figure, thus (Fig. 166); the transverse diameter being (when the line of motion of eccentric rod end is at right angles with the slide rod) the full travel, and equal to lap and lead of valve. In this position the engine will go either way round, the extremes occurring when it is on the centre. On varying angularly the line of motion of the eccentric rod end, the end of the valve rod still forms an elliptic figure, but the traverse of the valve is increased in proportion to the angularity, thus (Fig. 167), and on the extreme of the movement occurring after the engine has passed the centre, it will go back, or a-head way round, or as the line in which the rod end moves if turned to one side or the other of the square line for short traverse.

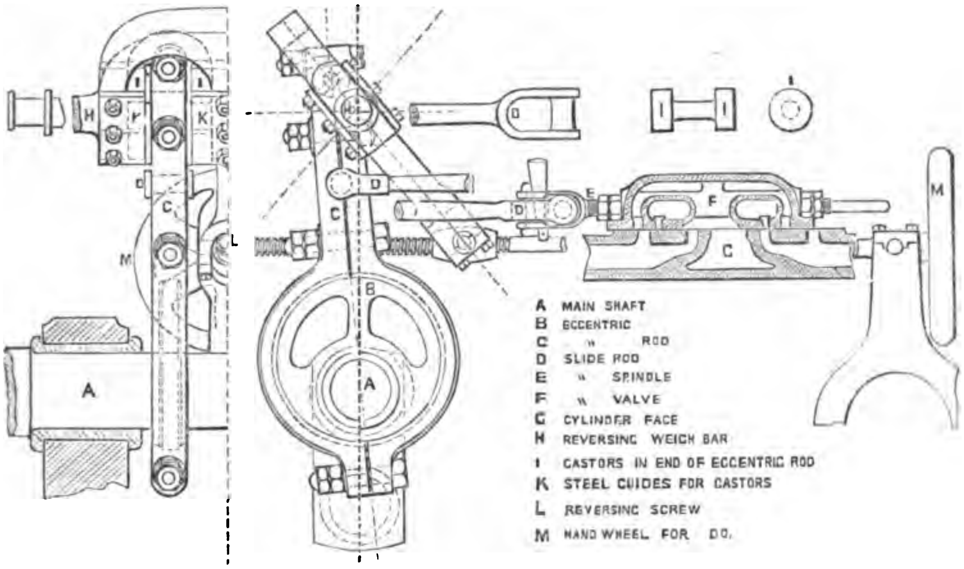
FIG. 166. FIG. 167.



Geometrical Diagrams of Hackworth's Expansion and Reversing Gear, as arranged in the year 1869.

The arrangement of the gear and form of valve proposed for marine or locomotive engines is shown by Fig. 168. As before stated, the movement of the valve is obtained from one eccentric, the rod of which performs the functions of a lever, having the valve rod attached thereto at right angles, and about two-thirds of its length from the centre of the straps that embrace the eccentric pulley, whilst the other extremity of the eccentric rod is guided by a parallel motion carried on a weigh shaft, the said motion answering as a fulcrum; and when the rectilinear movement runs through the centre of the main shaft, a proportionate amount of the eccentric's throw is communicated to the valve, being the "lap" and "lead." This is designated the "lead motion," the extent of which is at the option of the engineer, but when once determined remains invariable—the extremes of this movement occurring when the engine is on the centre gives the lead for either way round, and determines the relative positions of the crank and eccentric. A variable traverse and reverse action is produced by causing the parallel motion to move angularly on either side of the centre line as represented by a ×, one line giving the greatest supply of steam one way round, and the other the opposite; the supply being reduced as the line of motion approaches the centre, in which position the lead motion only is in action, the traverse being suspended. When both the lead and traverse are in action, one is at the middle of its traverse when the other is at the extreme, or in other words they are at right angles with each other in all similar cases.

FIG. 168.

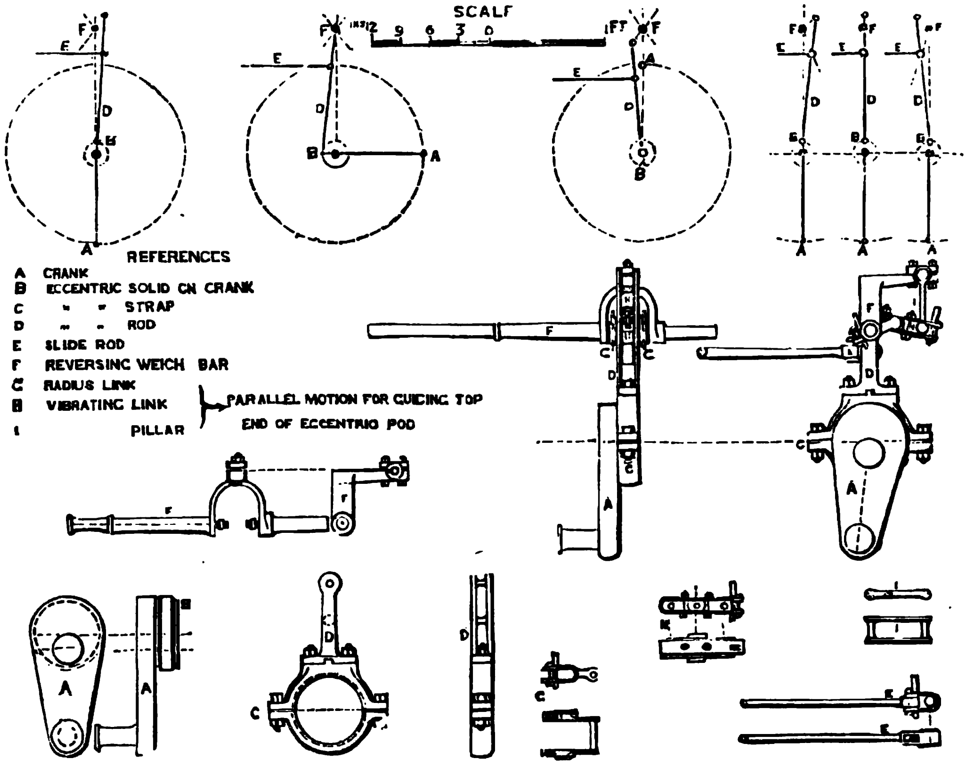


Hackworth's Single Eccentric Expansion and Reversing Gear and Valves, for Marine or Locomotive Engines, as proposed in the year 1869.

In some cases Mr. Hackworth has preferred to use a radius rod parallel motion for guiding the end of eccentric rod, as shown by Fig. 169 on the next page: this plan is very complicated and equally expensive.

But mostly has been proposed the steel castor running between steel parallel bars for guiding the rod end, as shown by Fig. 168; it has also been applied to marine engines, with a sliding block and brass face moving on an iron guide bar.

FIG. 169.

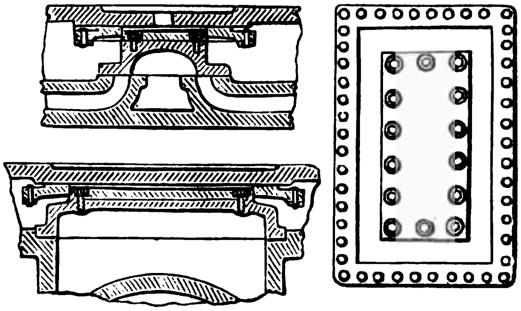


Hackworth's Single Eccentric Valve Gear, with a Radius Rod Parallel Motion, to guide the end of the Eccentric Rod, with Geometrical Diagrams and Details, as proposed in the year 1869.

We next refer to an example of a peculiar spring self-adjustable packing for the back of slide valves, by Mr. Dawes of Leeds, in which a separate plate is fitted to the back of the valve and surrounded by a frame plate; and the connections of the plates and valve are by metallic springs of suitable form; which connection or addition is termed by Mr. Dawes "an elastic packing."

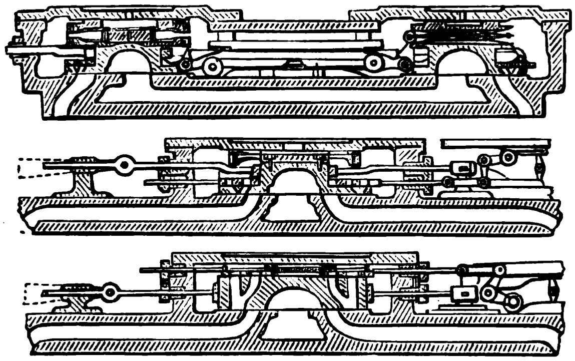
The construction of this packing will be best understood from Fig. 170, which illustrates two sectional views and a plan of the arrangement, where it will be seen that the packing is merely a spring or thin plate of metal that unites the frame plate to that on the back of the valve, so that the steam acts against the frame and the flanges of the valve at the same time; and thus the working face of the valve is relieved from the pressure that must otherwise occur.

FIG. 170.



Dawes' Elastic Spring-plate packing for ordinary Slide Valves; patented in the year 1869.

FIG. 171.



Dawes' Elastic-packing for Double-ported Slide Valves, patented in the year 1869.

The illustration, Fig. 171, shows three examples of valves having the same class of packing as before. The main valves are all double ported for the admission of the steam, and fitted with cut-off valves to correspond.

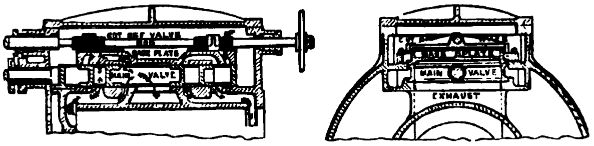
The gear for working those valves is partly shown in each elevation, and the arrangement for the upper one is thus:. upon the inner or exhaust end of each valve are fixed, by brackets, a pair of bell-crank levers, the upright arms of which are coupled—by rods passing along the sides of the main valves—to the ends of the cut-off valves or plates: and between the two horizontal arms a roller is bored and fitted upon a turned pin which is keyed into the ends of the arms of the bell-crank levers. About the centre of the steam chest between the two valves is fixed a differential movement of any convenient description in connection with the governor, so constructed that the rising or falling of the same shall cause the two broad wedge-shaped pieces to slide upon the bottom of the valve chest in contrary directions to each other, that is, as the governor rises they shall both move outwards from the centre towards the valves, and as the governor falls they shall both move inwards from the valves and towards the centre, and the position of these wedges with respect to the rollers is such that as the latter travel inwards with the valves they shall roll upon these broad wedges and thus—by the bell cranks and rods—close the cut-off valves alternately, and that earlier or later in the stroke of the piston according to the positions of the governor and the wedges. The sliding of the cut-off valves to open the ports at each stroke of the piston is effected by means of two fixed inverted wedge-shaped pieces attached to the steam chest over the said rollers, and so placed that when each of the main valves is at the end of its travel outwards, one of these fixed wedges and its roller shall have shifted or opened the cut-off valve for admitting steam in the cylinder, and close it again as the main valve travels inwards at the proper part of the stroke of the piston.

It may be well to explain that the surfaces of the before-named wedges upon which the rollers work, are not straight but S-shaped or double curved, so as to secure quietness of action and the further advantages of moving the cut-off valves only the distance required to close and open them and of opposing the least angle to the roller, and therefore having the greatest power at the beginning and ending of travel of the cut-off valves when, as will be evident, the greatest power is required to move them.

In applying this compensating wedge and roller action to the valves, as shown in the second or central sectional view, the separate cut-off plates or valves are fitted upon the outer flanges of the main valve and actuated in a similar manner; the wedges, the bell cranks, and rollers, are outside the steam chest, the connection between them and the valves being obtained by rods through packing boxes in the ends of the steam chest. It is evident, also, that the cut-off valves may in this arrangement be coupled to work together as one; or the cut-off plate or valve may work upon the back of the main valve, as shown by the lower section, in the usual manner or position, and the fixed inverted or opening wedges be dispensed with on account of the closing of the ports for one side of the piston and opening those for the other at the same time.

Being now on the theme of valves we notice next Mr. Gilchrist's valves, of which the principle, and pretty much of the practice too, is as Holcroft's arrangement, as shown by Fig. 157 on page 168, where the valves are single ported, but in this case are double ported, as shown by Fig. 172, in which the cut-off valves are separate from each end of the cylinder, and are screwed on a rod with right and left hand threads, so that adjustment, by the hand wheel, can be effected while the valves are in motion: these valves work on a face or back plate, that encloses the main valve, which regulates the expansion and

FIG. 172.

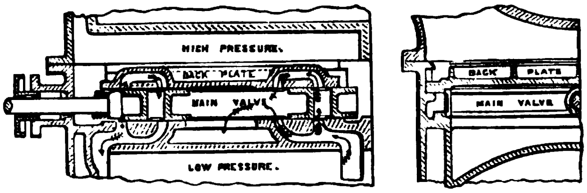


Gilchrist's Adjustable Cut-off Valves and Back Plate, and Equilibrium Main Valve for High-pressure Engines, patented in the year 1869.

exhaustion—as the arrangement is shown by two distinct sections it will be readily understood.

Mr. Gilchrist patented also the arrangement of valves, as shown by Fig. 173, which is of a more simple order than the previous example,

FIG. 173.

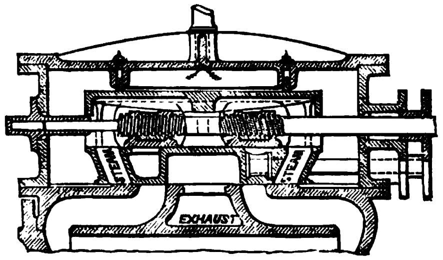


Gilchrist's Equilibrium Main Valve and Back Plate, for Compound Engines, patented in the year 1869.

and can be applied for compound engines also. The main valve for the low-pressure cylinder is single ported in its duty, and is in the form of a frame, with parallel faces with three openings through it; a narrow one at each end and a larger one in the middle. The cylinder bars are made with the exhaust port between them in the usual way, with the two ports and steam passage at the one end, and those with the other passage at the other end. The fixed back plate is made with its working face exactly like the cylinder port face, and opposite to each pair of passage ports there are two ports communicating with each other by a passage formed in the back plate. The movement of the main valve brings the narrow opening or valve port at one end of it alternately over the inner and outer ports of the cylinder passage at that end, and when it is over the inner port, as shown, the steam, as indicated by the arrows, has access directly to the outer port and to the corresponding opposite port in the back plate, by which last it enters the passage in the back plate and finds its way through the valve port to the inner passage port, but when the valve port is over the outer passage port, as is now with the port at the other end of the valve, the inner passage port communicates directly with the exhaust port, whilst the outer port also communicates therewith through the valve port and through the passage in the back plate. The same actions of course take place at both ends, but alternately. The back plate for either arrangement may be fixed in the valve casing in any convenient way, as, for example, by taper keys or wedges which hold it between ribs formed in the sides of the casing as in the low-pressure casing, or it may be bolted to lugs or flanges as shown in the high-pressure casing. The valve of the high-pressure cylinder and its back plate, Fig. 172, have the same ports and passages as the valve and its back plate, Fig. 173, and they only differ in the additions required when applying cut-off valves.

We illustrate next, by Fig. 174, an ordinary arrangement of valves worked separately; and also by which the pressure of the steam on the back plate is reduced by a packing ring in the casing cover. The cut-off valves are in this case contained in the back plate, and the main valve below formed with the back plate is single ported. It will be noticed that this arrangement differs a great deal with that shown by Fig. 172 on page 179: there the back plate is fixed, but in this case it moves with the main valve it is a portion of: the advantage with this is, that the area exposed to the pressure of the steam can be reduced to a minimum; or, if desired, the surface areas can be so proportioned that the steam can lift the valves from the cylinder faces rather than press the valves on them.

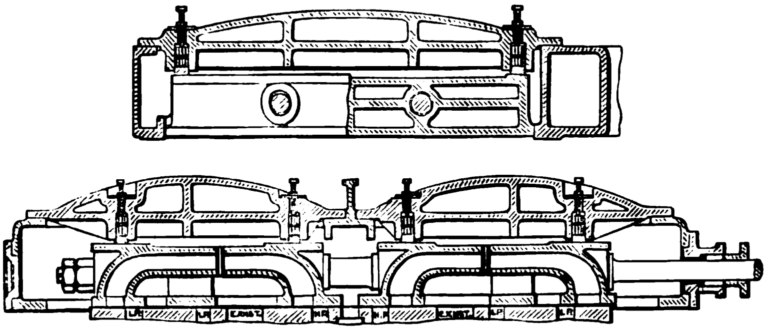
FIG. 174.



Ordinary Adjustable Cut-off and Equilibrium Main Valves for Steam Engines, applied in England and America since the year 1865.

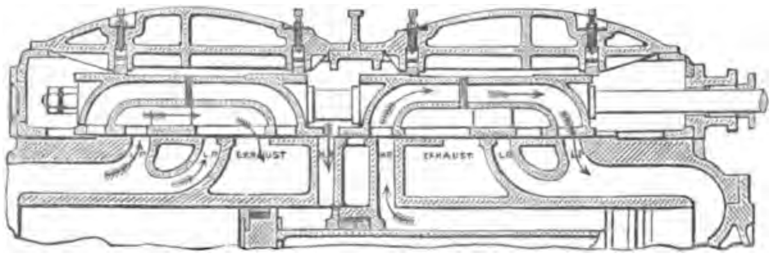
Whilst on this subject it will be as well to allude to a new type of valve for a compound engine, constructed by Messrs. J. and G. Rennie, as illustrated by Fig. 175, on the next page. This is arranged for the uses of high and low pressures steam at the same time; the former first doing duty in the small annular space, and then performing the latter in the main cylinder. We have shown this view at half stroke, with the transverse section over it; but to make its utility easily to be appreciated, it is illustrated again at full stroke by Fig. 176, as all the arrows depicting the steam's action are shown, that can be understood without description.

FIG. 175.



Rennie's Arrangement of Double Ported Equilibrium Slide Valves, for one of the Compound Engines (Allen's Patent) fitted by them in H.M.S. "Spartan" in the year 1869.

FIG. 176.

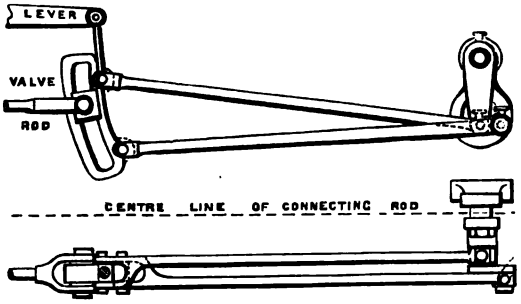


Rennie's Arrangement of Double Ported Equilibrium Slide Valves, for one of the Compound Engines (Allen's Patent) fitted by them in H.M.S. "Spartan" in the year 1869.

Leaving the subject of valves, we resume that of link-motion and direct attention to a novel arrangement, as illustrated by Fig. 177, which shows that the link rods are attached to and receive motion from cranks and pins in the place of ordinary eccentrics, being the return crank motion as shown by Fig. 138 on page 151. This was fitted to a locomotive engine in America, and to the present has given moderate satisfaction.

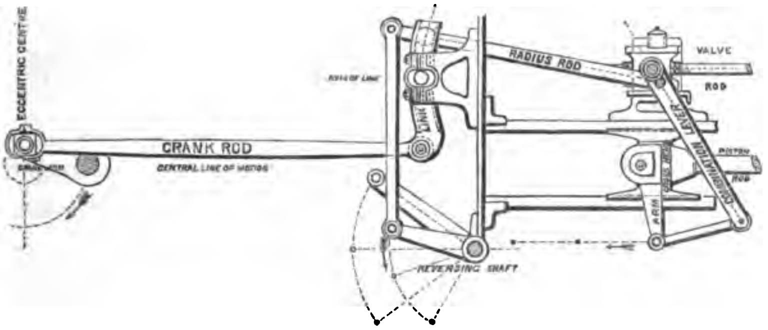
Another class of link-motion is shown by Fig. 178; this is the return crank gear also, in combination with rods and levers worked by the main piston rod, which was originated by M. Waldegg, a German engineer, as far back as the year 1857—illustrated on page 71—and since that has been rearranged, as here shown, being now termed the Walschaërt's gear, from the name of the French engineer who altered it.

Fig. 177.



Return Cranks, Link Motion, constructed at Palnan, U.S., in the year 1869.

Fig. 178.

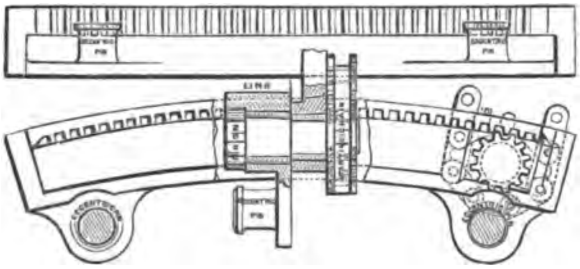


Walschaërt's Link Motion and Lever Valve Gear for Locomotive Engines, adopted mostly in Belgium during the last ten years, or since the year 1860.

The action of the gear is this: the link is hung on a pin centrally situated, and the lower end is in connection with the return crank pin, which, of course, performs the function of an eccentric. The motion of the link is transmitted by a block and rod to a valve-rod lever, and the raising and lowering of the block to the limits above and below the centre pin alters the valve "lead" from one to the other end of the cylinder; the valve-rod lever, it will be seen, is in connection at the top end with a block fixed on the valve rod, and at the lower end, by a rod to an arm on the cross-head of the main piston rod. The motion of the valve is therefore alone constant from the piston rod when the link block is on the centre of the vibrating pin, and exceptional or in combination with that of the crank pin when the block is raised or lowered from the central position.

Another novelty of link-motion must now be referred to, which is illustrated by Fig. 179; this is the toothed type worked forward and backward by a pinion that receives motion from a starting chain, as applied to paddle wheel, vertical direct-acting engines, as far back as the year 1843, by the late G. Rennie, Esq., F.R.S.; and when it is remembered that the link-motion was invented for locomotive engines, by Mr. Howe, only one year before, it is evident Mr. Rennie took the matter in hand for marine purposes as soon as he knew of it.

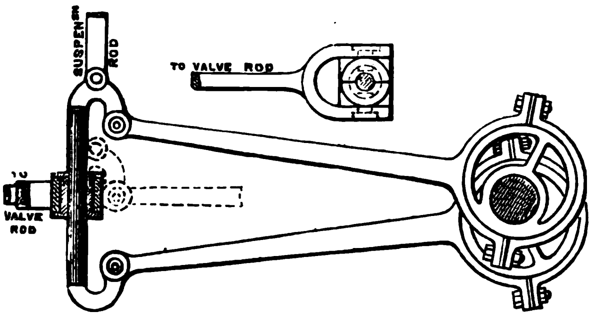
FIG. 179.



Elevations of the Link fitted to the Paddle Wheel Engines of H.M.S. "Sampson," by Messrs. G. & J. Rennie, in the year 1843.

As a contrast to Mr. Rennie's quickness in this matter, Messrs. Smith and Stevenson's slowness can be put forward, for it was only until the latter end of the year 1869 that they patented the arrangement of link-motion as shown by Fig. 180, which is a copy of Mr. W. Robertson's; as shown on Plate 55, that he invented in the year 1857; excepting that Mr. Smith turns the ends of the link up and down to joint the eccentric rods in a line with the slide valve rod, which, by-the-way, is but the common slotted link connection with that evil also.

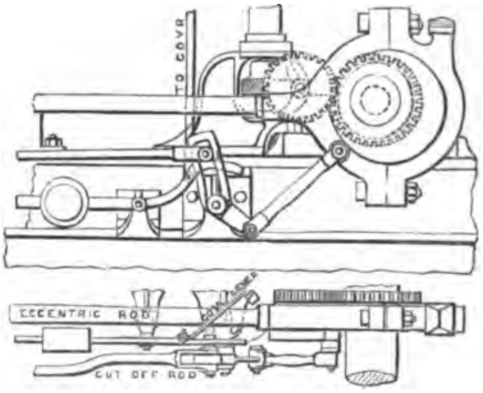
FIG. 180.



Smith's Solid Straight Link Motion, having the ends of the Link turned up and down to connect with the eccentric rods, patented in the year 1869.

Leaving the link-motion we again revert to the land engine valve gear, and direct attention to that illustrated by Fig. 181, which is an arrangement of lever motion in connection with an ordinary eccentric and ball-governor gears by Messrs. Marriott and Holt of Manchester, in which the ordinary eccentric that works the main valve, is also attached by a rod to a lever, formed with a link, while in this link is fitted a block, in connection by rods with the cut-off valve and the ball-governor sliding block, by which arrangement the latter valve is not only worked by the eccentric, but that travel is also regulated by the action of the governor raising the block in the link. The spur gearing and worm imparts the motion from the crank shaft to the governor spindle, as shown in the plan

FIG. 181.

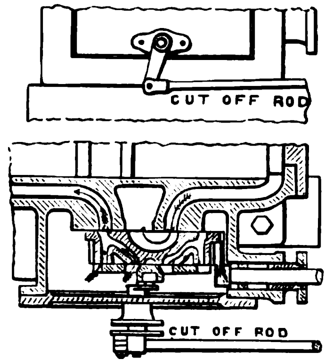


Marriott's Expansion Gear regulated by a Ball Governor, in connection with Common Eccentric Gear for working the Cut-off and Main Valves of an Engine, patented in the year 1870.

and elevation, from which views the relative positions of the link and rods can also be seen.

Now if we turn to page 61 we shall see there that Mr. Marriott and his friend were fully anticipated in relation to their gear, and that their arrangement of valves, as shown by Fig. 182, are as those illustrated on page 161 by Fig. 148.

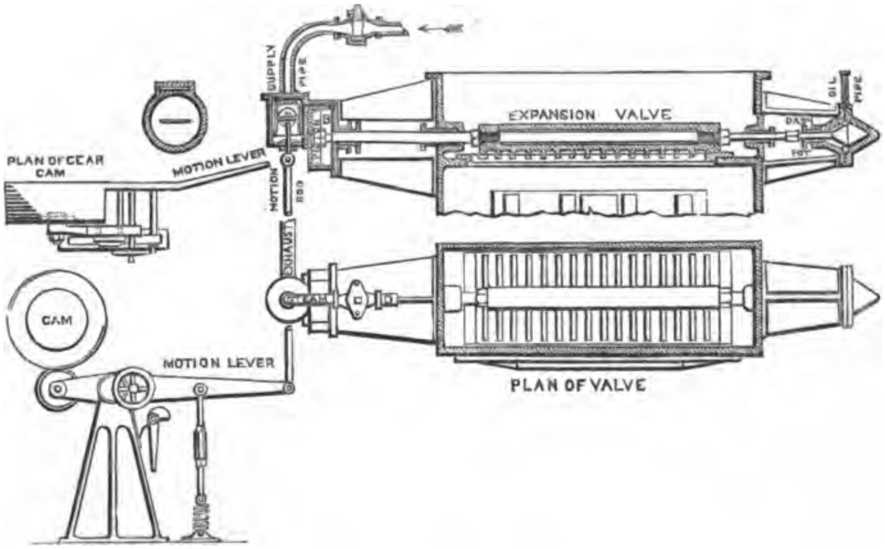
Fig. 182.



Marriott's Valves in connection with the Gear, illustrated by Fig. 181, patented in the year 1870.

Our purpose next is to describe and illustrate an expansion gear and valve, as shown by Fig. 183, that has been designed by a Mr. Edgar, an engineer, R.N., who proposes an ordinary cam motion gear with a spring to keep the roller against the cam, as shown in Plate 34, but the position of the roller to be regulated by a screwed rod and handle in this case: the cam-lever is in connection

Fig. 183.



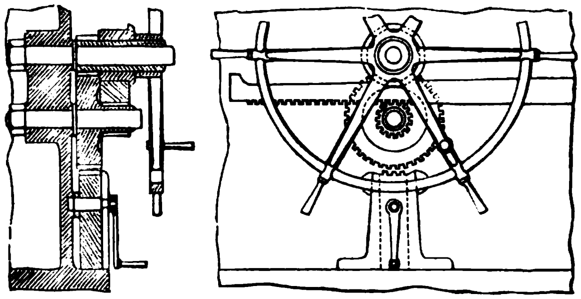
Edgar's Steam Motion Expansion Gear, in combination with the ordinary Cam Gear and Spring for working the Gridiron Expansion Valve, proposed in the year 1870.

with a tubular equilibrium steam valve that regulates the flow and exhaust of steam into and from a small cylinder, having a piston in it that is driven forward and backward as the proportions and motion of the valve determines: this piston has a rod fitted through it, which is secured at the other end to an ordinary gridiron expansion valve, by which connection that valve is actuated. Now the motion of the valve, of course, depends on that of the piston, so that if the latter is driven back suddenly it causes the valve to open the ports under it, and while the piston remains still the valve does also: on the steam being admitted to the other end of the cylinder the piston is reversed in position at once and the gridiron valve closes the ports and remains in that position until the piston moves back again: the whole feature then of the arrangement lies in the "jerking" of the piston by the steam, and in order to deaden the blow, a conical dash-pot, with a suitable piston, is situated at the extremity of the piston rod beyond the gridiron valve. All this, however, has been carried out before in a better manner, as shown by Plate 39 B.

Before closing this chapter we will explain and illustrate a few novel examples of starting gears that are not shown in the plates.

Messrs. Humphrys, Tennant and Co. have for the last ten years used the arrangement as shown by Fig. 184, which consists of pinions and a rack motion, in connection with the usual hand wheel. This firm,

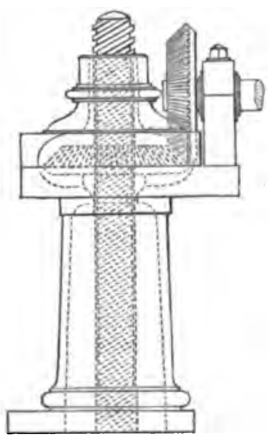
FIG. 184.



Humphrys' Hand Starting Gear for raising and lowering their Link Motion for Screw Engines; as used from the year 1862 to the present time.

although the present sole adopters of this gear, were not the originators of it, because Messrs. Maudslay, Sons and Field used a similar contrivance eighteen years ago, but the rack was situated vertically instead of horizontally, as illustrated, and was arranged that the foot plate is level with the base of the engine as in both cases; but in the first case the rack is situated at the side of the feed pump chamber and condenser, and in the second at the side of the slide valve casing of the engine cylinder. Messrs. Maudslay used one pinion only to gear with the rack, whose lower end was attached to the link, and thus, on turning the hand wheel, the effect was accomplished, while Messrs. Humphrys, to gain power with less speed, used three pinions of unequal diameters arranged as follows: centrally of the length of the feed chamber is secured a pin fixed by a nut on the inside end, and a tube with a pinion formed with it is supported on this pin; the starting wheel is secured on the tube part, and thus the pin supports them both: the pinion gears with a small tooth wheel below it, which is also supported on a stationary pin fixed as the other above; this wheel has formed with it a pinion that gears with the rack that is in connection with the link levers, the rack being kept in gear by a roller on the tube of the first pinion. Obviously then on the turning of the hand wheel, the pinion moves the tooth wheel and it turns the pinion in gear with the rack, and thus the link is shifted in the required direction—a lock-gear is also used that consists of a tooth piece, which, when in gear with the tooth wheel, prevents its motion in either direction to shift the rack.

FIG. 185.

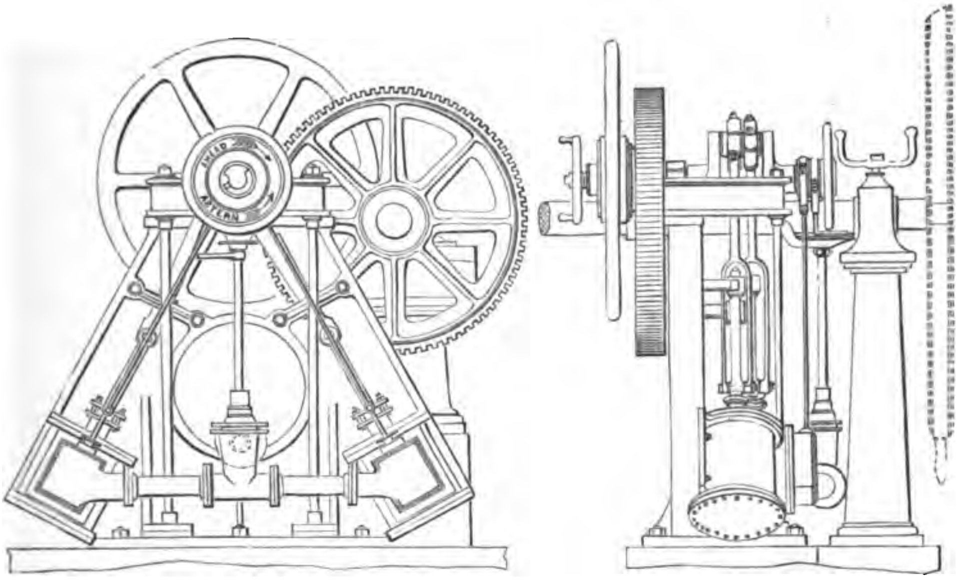


Maudslay's Support Pillar and Hand Gearing for raising and lowering their Link Motion for Screw Engines; as used from the year 1862 to the present time.

The same effect can be obtained at a cheaper rate by mitre-gearing and a screwed rod, introduced by Messrs. Maudslay about twelve years ago, as illustrated by Fig. 185, which shows the vertical support pillar, pinions, and rod, in elevation; but of course this can be arranged horizontally also with the same result, as in either case the screw rod is in connection with the link and the starting rod, that is actuated by the hand wheel.

Hand power, however, is not always sufficient with engines of large size, because the link-motion and the slide valves are very heavy and cumbersome, and to overcome or shift them, steam starting gear is employed, as illustrated by Fig. 186, and arranged by Messrs. Maudslay.

FIG. 186.

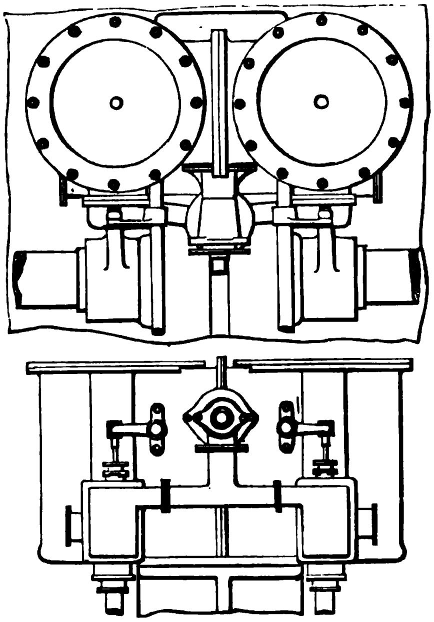


Maudslay's Steam Starting Gear, for raising and lowering their Link Motion for Screw Engines; as used from the year 1862 to the present time.

This gear consists of two angular direct-acting steam engines with single eccentric valve gear—but link-motion gear with two eccentrics have been used also—and on the engine shaft there is a tooth pinion in gear with a tooth wheel on the starting shaft, which latter has on it a hand wheel also, to be used in cases of emergency; there are also an indicating disc-fly wheel and stop clamps, or hand spanners, by which the direction of the engines are regulated.

Now, although that arrangement may seem clever and very efficacious, it has the fault of many details, which is entirely eradicated by the arrangement shown by Fig. 187, as introduced by Messrs. Ravenhill, Hodgson and Co.: here we have direct connection and action from the starting engine piston to the lever on the link weigh shaft, with the entire absence of spur gearing shafts and bearings and their attendant casualties. The course for the steam required to shift the pistons is regulated by hand gear-slide valves, by which means very little wrist power can start the largest engines when proper proportions are carried out for the starting cylinders.

FIG. 187.



Ravenhill's Steam Starting Gear, for raising and lowering their Link Motion for Screw Engines; as used from the year 1862 to the present time.

CHAPTER III.

THE GEOMETRICAL PRINCIPLES OF THE ACTION OF ECCENTRICS AND LINK-MOTIONS, ACCORDING TO THEIR RELATIVE POSITIONS, AS APPLIED FOR VALVE GEARS OF STEAM ENGINES.

INTRODUCTION.—The principles of valve-gearing mechanically change so much with the arrangement of the details, that calculations, unless relative to those circumstances, are useless. Yet with this, as a known fact, we have in a certain work on valve gears calculations given, in which all the problems of Euclid and algebraic formulæ possible are involved, and this would not be out of place, indeed, if our working engineers were educated up to that standard; but as they are not, then all the crossing of lines, fine writing, and symbols are lost for practical purposes, and their use only serves to astonish rather than instruct their readers. The answer to this may be, "educate your men to meet the case;" but even were this possible, then those geometrical rules and calculations, in nearly every instance, would be useless in practice; and "practice," it must be remembered, is the main point; in fact, the climax of all our endeavours and study.

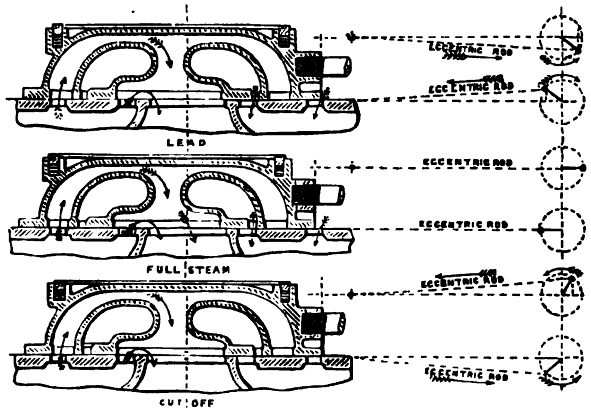
What then is required, is plain simple geometry of the same class and order represented as the engine is intended to be; that is, don't put in supposititious events or occurrences to disturb the proper action, but settle first the best *practical* means available, and work to that only; keeping in mind all the requirements for adjustment and repair. Now those two last features are the very things that we who are practical notice first, and the very things that the heavy calculators never notice at all; and why is this?—it is the result of plain common sense, matured by hard study and genuine substantial thinking, against the result of the soaring of the aspiring imagination of those who think only to please themselves when in their own element of self-delusion.

Practical Preliminaries.—To begin this properly is to settle first the travel of the valve, next the length of the eccentric rods, then the form of the link, after that how to suspend it, and lastly, the kind of reversing gear. Now all those four functions form valve-gear or link-motion, and unless their relative proportions and positions are fully taken into account in the geometry and calculations, false conclusions must occur. The travel of the valve settles the throw of the eccentric; the length of the rods determines the action of the eccentric on both sides of the centre of the shaft; on the form of the link depends the loss of motion given by the eccentrics, and the suspension of the link is also accountable with that; while the kind of reversing gear affects the expansion duty of the link as well as the power to raise and lower it. But to fully explain all those particulars practically we must consider first the valve and eccentric motions and the consequences of certain lengths of eccentric rods.

The illustration, Fig. 188, shows a slide valve of the most modern kind, in the positions for lead, full supply steam and cut-off, also the length of the eccentric rod and the relative angles of the eccentrics. Now strict attention and remembrance of the fact must be considered, that as the position of the piston is affected by the length of the connecting rod, so will that of the slide valve be affected by the length of the eccentric rod; both shaft motions are circles, and both rods are radii of larger circles; and put the matter in any form, these facts are the same. We know that the connecting rod is a radius, whose arc, intersecting with the centre line of motion, will determine a relative position for the piston, and therefore in no case can the angles of the crank be alike, when the positions of the piston are of equal distances from the ends of the strokes.

Now the eccentric's travel and rod are subject to the same cause, therefore the effect must be the same as already stated. Turning to the diagrams again for further explanation, Fig. 189 represents the circle of an eccentric travel, 11 inches in diameter, the lead for the valve being $\frac{1}{2}$ inch, outside lap 4 inches, width of steam supply opening, caused by the valve, $1\frac{1}{2}$ inch, and length of eccentric rod only 36 inches. Next, notice that the length of the chord intersecting at the parts of the circle nearest the valve, is shorter than the one opposite; hence the versed sines, V V, are, in relation to that circumstance, also due to the radius of the circle being unalterable. The valve having an equal lead when the piston arrived at each end of its stroke, the points L L are due to the length of the eccentric rod, which determines an unequal position for the angle of the eccentric above, and below the

FIG. 188.



Diagrams of a Slide Valve, Eccentric, and Rod, at their forward and backward positions; for lead, full steam and cut-off, when the length of the Rod is $5\frac{1}{2}$ times the travel, and the lead $\frac{1}{30}$th of the same.

FIG. 189.

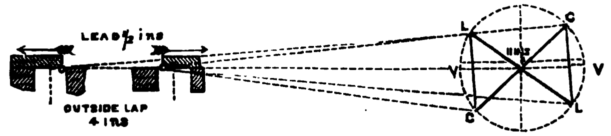


Diagram of the positions of the Eccentric and Valve for lead (L) and cut-off (C), when the length of the Rod is $3\frac{1}{3}$ times the travel, and the lead $\frac{1}{22}$ of the same.

centre line. Here it must be remembered that the eccentric in practice moves with the crank, and no relative alteration of angle can occur; but it is essential in the present instance to assume the angles changed due to the length of the eccentric rod, if an even lead is required. The points, C C, are the angles of the eccentrics when the valve is cutting off the steam, and as the arc, L V, above the centre line is unequal to V L below opposite, so also will V C above and V C below be unequal.

Compare next the diagram, Fig. 190, with the one just explained.

FIG. 190.

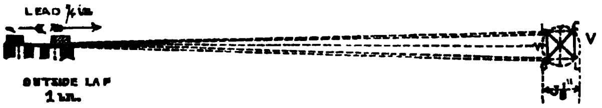


Diagram of the positions of the Eccentric and Valve for lead (L) and cut-off (C), when the length of the Rod is $14\frac{3}{4}$ times the travel and the $\frac{1}{12\cdot5}$ of the same.

Here the eccentric's travel is only $3\frac{1}{8}$ inch, the lap 1 inch, lead $\frac{1}{4}$ inch, width of opening $\frac{9}{16}$ inch; but the eccentric rod is in this case 46 inches long, so that L V and V L are nearly equal, and C V and V C bear a similar comparison with each other, and make but very little difference in the versed sines. In Fig. 189 the lead is $\frac{1}{8}$th of the outside lap, but in this case the lead is quarter of the lap, while the versed sines, V V, also are nearly equal to each other.

Fig. 191 is another proportion; the outside lap is 2 inches, lead $\frac{1}{8}$th inch

FIG. 191.

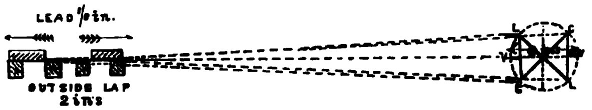


Diagram of the positions of the Eccentric and Valve for lead (L) and cut-off (C), when the length of the rod is 7 times the travel and the lead $\frac{1}{48}$th of the same.

or $\frac{1}{16}$th of the lap, width of opening caused by the valve, 1 inch, diameter of eccentric circle, 6 inches, and the length of the eccentric rod 42 inches. Here C V and V C are nearly equal; while L V and V L bear the same relation; also the versed sines V V.

FIG. 192.

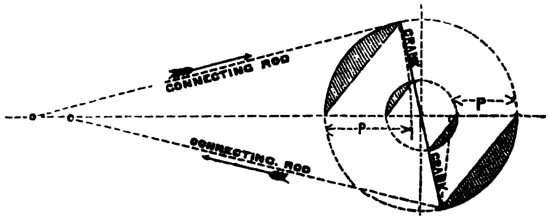


Diagram of the angles of the Crank and connecting Rod, for an unequal Grade of Expansion; but equal versed sines of travel for the Crank-pin and centre of the Eccentric.

FIG. 193.

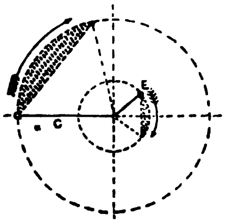


Diagram of the angles of the Eccentric for lead and cut-off by the Valve, when the Crank is at the left hand.

FIG. 194.

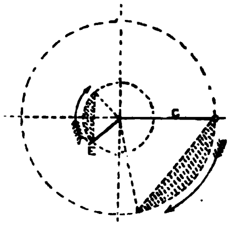


Diagram of the angles of the Eccentric for lead and cut-off by the Valve, when the Crank is at the right hand.

It is further demonstrated by the diagram, Fig. 192, that the versed sines of the crank and eccentric are alike in proportion. It is seen when the crank has passed through equal arcs, also the eccentric, that the chords and versed sines are relatively equal, but the grades of expansion, P P, are, of course, unequal. We shall understand this better from the diagrams, Figs. 193 and 194. The cranks, C C, are shown in opposite directions, and the angles of the eccentrics, E E, due to the lead required; when the crank in Fig. 193 is rising, the eccentric is descending, as shown by the arrows, and reverse in Fig. 194. Another fact is, that this unequal grade of expansion is also due to the connecting and eccentric rods being on the same side of the crank shaft, so that the arcs of position, for both piston and valve, are in the same direction. This is the fault with all direct-acting engines, and although the fault may be remedied by unequal laps and leads, the principle of the action remains the same; hence this axiom, "that if lead is equal, at each end of the stroke, expansion must be unequal at both sides of the piston, with direct-acting engines."

Now, having shown the bane, we will produce the antidote given by the diagrams, Figs. 195 and 196. This is the return-acting type of engine as far as the positions of the connecting-rod and slide-valve are affected. The arcs—not shown—of positions for the piston are equidistant from the limit of the circle, C C; the arcs passed through by the cranks, C C, are, of course, unequal, and those described by the eccentric are the same. When the crank is on the horizontal line, the angle of the eccentric is shown by the dotted line above the horizontal line, and as the crank on rising passes through a certain length of the eccentric circle, the eccentric descends through a similar distance. Now the length of the connecting-rod is five cranks or radii of the crank circle, and due to that length are the arcs of position. Decided attention must be given to the fact that those arcs incline in a certain direction.

FIG. 195.

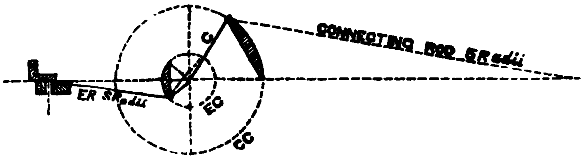


Diagram of the relative positions of the Slide Valve and Guide-end of the piston-rod connecting-rod, to produce an equal lead and equal grade of expansion during each stroke of the piston: the lengths of the Eccentric and Connecting Rod being of the same proportion to their travels.

FIG. 196.

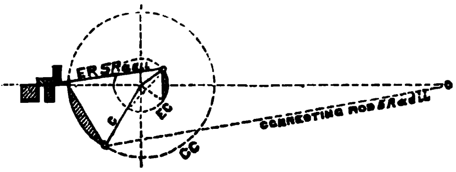


Diagram proving the application of the proportions. Shown in Fig. 195 in a reverse position.

The slide-valve is situated opposite the connecting-rod, and the length of the eccentric-rod E R is five radii of the eccentric circle. The arcs of the valve's position are thus relative, in a contrary direction to those for the piston. Those arcs, therefore, being proportionate, but in opposite directions, a relative action must be certain.*

LINK-MOTION.—When the link is used as a medium between the ends of the eccentric and valve rods, the principles just explained remain as before, as far as the positions of the eccentrics and length of their rods are effected; but the motions of the ends of the rods, instead of being sliding only, have the additional movements of rising and falling also, or vibrating to and fro, so as to form cross-curve lines, which will be fully explained hereafter.

We will now investigate the difference in the positions of the link when the rods are crossed, and not crossed, in order to lead up to final matters for correct conclusion.

The diagram shown by Fig. 197 is a sectional elevation of a double

FIG. 197.

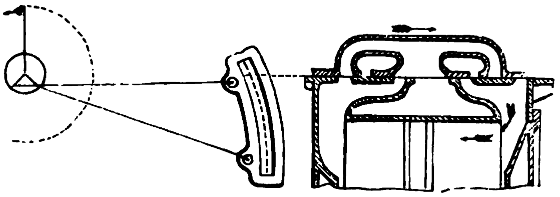


Diagram of the Link-Motion and Slide Valve, with the Eccentric Rods *crossed* and the Link "down," for direct action, the Valve "cutting-off."

FIG. 198.

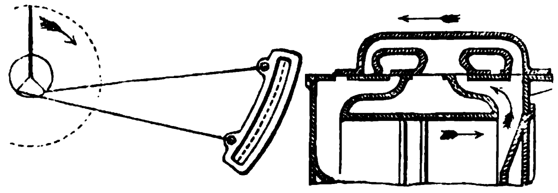


Diagram of the Link-Motion and Slide Valve, with the Eccentric Rods *not crossed*, and the Link "down" for direct action, the Valve "cutting off."

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* This was explained first by the author in a lecture at the Society of Arts in December, 1867.

ported slide-valve and portion of a cylinder to correspond with the link in a certain position, due to the eccentric rods being crossed and the crank vertical; producing therefrom an unequal lead at each stroke of the piston, which, of course, should be avoided by connecting the eccentrics and link, as shown by Fig. 198. It will be seen also that the relative positions of the links and valves are entirely opposite to each other; as, for example, in Fig. 197, the top of the link inclines towards the shaft, but in Fig. 198 it inclines towards the valve, and the movements of the crank and valve are in reverse directions also.

The next illustration, Fig. 199, shows the link and valve midway, or at half stroke, when the eccentric rods are crossed and the crank vertical; and Fig. 200 illustrates the same details with the rods not crossed; here, again, the links are oppositely situated, although the valves are not so.

FIG. 199.

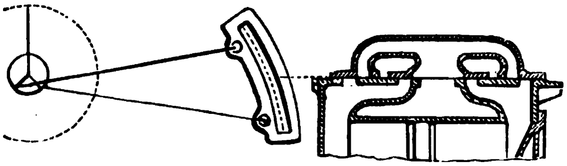


Diagram of the Link-Motion and Slide Valve, with the Eccentric Rods *crossed*, the Link "midway," for direct action; the Valve at "half stroke."

FIG. 200.

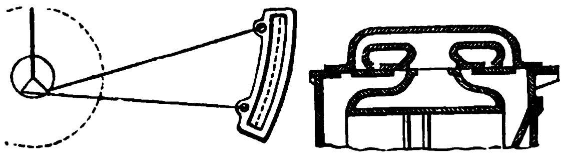


Diagram of the Link-Motion and Slide Valve, with the Eccentric Rods *not crossed*, and the Link "midway" for direct action; the Valve at "half stroke."

It will be remembered that the links in Figs. 197 and 198 were *down*, therefore we now illustrate the same valves, &c., when the links are *up*, by Figs. 201 and 202. The valves are in reverse positions, and the position of the link in Fig. 201 contrasts widely with that in 202;

owing, of course, to the eccentric rods being crossed in the one case and not crossed in the other. We next direct attention to the uniform positions of the links in Figs. 197, 199, and 201, all inclining towards the shaft, and as a contrast, to those shown by Figs. 198, 200, and 202, inclining towards the valve, which is the right way as much as the other is the wrong.

FIG. 201.

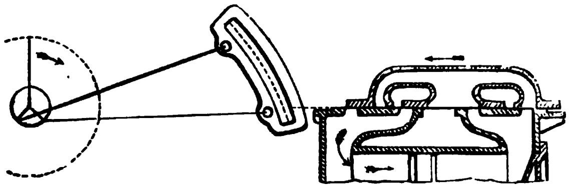


Diagram of the Link-Motion and Slide Valve, with the Eccentric Rods *crossed*, and the Link "up" for direct action: the Valve "cutting off."

FIG. 202.

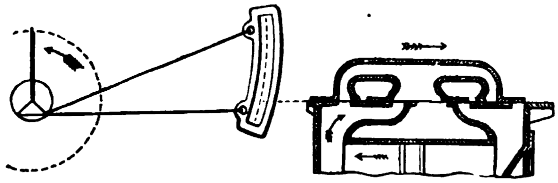


Diagram of the Link-Motion and Slide Valve, with the Eccentric Rods *not crossed*, and the Link "up" for direct action: the Valve "cutting off."

ADJUSTABLE ECCENTRICS.—Having thus far investigated the performances of the fixed eccentrics, we will now explain the duties involved with adjustable eccentrics; as, for example, in the diagram, Fig. 203 on the next page, the eccentric has an angular advance of $33\frac{1}{2}°$ or a position C F, suitable for a positive or forward motion of the crank if a lever intervenes between the eccentric and the valve. It must be understood, also, that the same eccentric, when situated at an opposite angular advance C B, holds a position appropriate to a negative or back motion of the crank. Hence if it be required to change the direction of the engine's motion, it is only necessary to unkey the eccentric, slip it around the shaft, and secure its throw in a position C B, opposite to that of C F.

But if in addition to a change of direction a variation in the cut-off for the forward and back motions of the crank were demanded, subject to the single condition that the lead opening and lap shall remain unaltered, then it would be very clear that the eccentric must be slotted in such a manner that its centre can pass in a *direct* line from F to B instead of following the arc F *m* B. By this means the throw of the eccentric, and consequently the travel of the valve, would be reduced between F, the full gear forward of the eccentric, and B the full gear back, while the minimum value would lie at the point M midway between those extremes, or at the mid gear of the eccentric. When the eccentric is placed at f^2, the $\frac{1}{2}$ travel of the valve equals $c\,f^2$; at $f^3 = c\,f^3$ and at the mid gear $=$ C M.

Fig. 203.

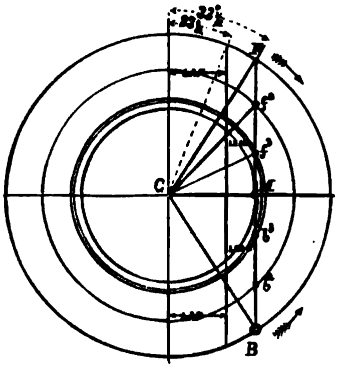


Diagram of an Adjustable Eccentric's travel-circle, with *constant* lead.

Fig. 204.

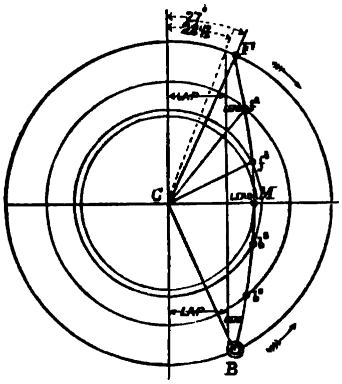


Diagram of an Adjustable Eccentric's travel-circle, with *variable* lead.

Now when the lead is required to be variable, so as to make the valve cut-off equal on each side of the piston, the diagram, Fig. 204, illustrates the proceedings requisite, or where the centre of the eccentric is shifted on an arc instead of a straight line as before, while the figs. and letters of references are the same in each case.

Suppose next that C F, the radius of the eccentric circle, or full throw of the eccentric, is $2\frac{1}{2}$ inches:

Then the greatest travel of valve . . . = 5 inches
Suppose the lap . . . . . = 1 „
And lead opening . . . . . = $\frac{3}{8}$ „

These dimensions are chosen on account of no peculiar fitness in their relation to one another, but merely to illustrate the effect of reduced travel, constant lap, and a variable or constant lead upon the cut-off, lead angle, port opening, and exhaust closure of a simple slide valve.

With a *Constant Lead opening* the centre of the eccentric should be moved in a direct line from F to B, Fig. 203. When situated at F, the travel of the valve equals twice C F = 5 inches, the lap = 1″, and lead = $\frac{3}{8}$″; if now we mark the lap and lead on a slip of paper, and apply it in the usual manner, we find that

The cut-off = 123° = 0.77 stroke.
The lead angle = 10 degrees.
The port opening = $1\frac{1}{2}$ inches.
The exhaust closure = $146\frac{1}{2}$° = 0.92 stroke.

Upon removing the centre of the eccentric from F to f^2 the travel will be reduced to twice C F^2 = 4″. Lap and lead opening remaining unchanged, we find, by applying them to the 4″ travel, that

The cut-off = 106° = 0.64 stroke.
The lead angle = 14 degrees.
The port opening = 1 inch.
The exhaust closure = 136° = 0.86 stroke.

Since b^2 is removed the same distance from B that f is from F, the two positions f^2 and b^2 will give precisely the same results for opposite motions of the crank.

In a similar manner the cut-off, etc., for the positions f^3, b^3, and M may be readily found, but their mutual relation can best be exhibited by grouping their results in a Table like the following for—

Constant Lead.

Eccentric's Positions.	Travel.	Lap.	Lead opening.	Cut-off.	Lead angle.	Port opening.	Angular advance.	Exhaust Closure.
	Deg.	Deg.	Ins.	Deg.	Deg.	Deg.	Deg.	Deg.
F or B	5	1	$\frac{3}{8}$	123 $=0\cdot77$ stroke.	10	$1\frac{1}{2}$	$33\frac{1}{2}$	$146\frac{1}{2}=0\cdot92$ stroke.
f^2 or b^2	4	1	$\frac{3}{8}$	106 $=0\cdot64$,,	14	1	44	136 $=0\cdot86$,,
f^3 or b^3	3	1	$\frac{3}{8}$	71 $=\frac{1}{3}$,,	25	$\frac{1}{2}$	67	113 $=0\cdot695$,,
M	$2\frac{3}{4}$	1	$\frac{3}{8}$	$43\frac{1}{2}=0\cdot14$,,	$43\frac{1}{2}$	$\frac{3}{8}$	90	90 $=\frac{1}{2}$,,

Again, with *Variable Lead opening*, diminishing from the mid gear towards the full gears (from $\frac{3}{8}''$ to $\frac{1}{8}''$) the centre of the eccentric must move in the arc of a circle, as shown in Fig. 204, where the points f^2, f^3 are drawn a little nearer towards the centre of the shaft, thereby reducing the travel of the valve. A Table similar to the above has been constructed for showing the effect of the action for—

Variable Lead.

Eccentric's Positions.	Travel.	Lap.	Lead opening.	Cut-off.	Lead angle.	Port opening.	Angular advance.	Exhaust Closure.
	Deg.	Deg.	Ins.	Deg.	Deg.	Deg.	Deg.	Deg.
F or B	5	1	$\frac{1}{8}$	$129\frac{1}{2}=0\cdot82$ stroke.	$3\frac{1}{2}$	$1\frac{1}{2}$	27	153 $=0\cdot945$ stroke.
f^2 or b^2	$3\frac{7}{8}$	1	$\frac{1}{4}+\frac{1}{32}$	107 $=0\cdot65$,,	$10\frac{1}{2}$	$\frac{15}{16}$	$41\frac{1}{2}$	$138\frac{1}{2}=\frac{7}{8}$,,
f^3 or b^3	$2\frac{15}{16}$	1	$\frac{5}{16}+\frac{1}{32}$	71 $=\frac{1}{3}$,,	24	$\frac{7}{16}+\frac{1}{32}$	$66\frac{1}{2}$	$113\frac{1}{2}=0\cdot7$,,
M	$2\frac{3}{4}$	1	$\frac{3}{8}$	$43\frac{1}{2}=0\cdot14$,,	$43\frac{1}{2}$	$\frac{3}{8}$	90	90 $=\frac{1}{2}$,,

From a comparison of the foregoing tables we are enabled to draw the following general conclusions:

I. That whether the eccentric centre be moved along a straight line, or upon an arc, the nearer its approach is to the mid gear, the cut-off and exhaust closure will take place the earlier; while the lead angle and angular advance of the eccentric will be increased accordingly.

II. At the mid gear—

The port opening = the lead opening of the valve.
Cut-off angle = lead angle of the valve.
Angular advance = 90°.
Hence the exhaust closes at the ½ stroke.

III. If the port opening = 0, in the mid gear, then the lead opening = 0, and the lead angle = 90°. The steam consequently is not admitted to the cylinder for either stroke of the piston.

IV. Since the free admission of the steam depends directly on the area of the port opening, and this is gradually reduced towards the mid gear, it must be evident that the *most influential* element upon the perfect action of a link motion, or adjustable eccentric, will be this width of lead opening in the mid gear; at which position it should equal the port opening.

V. Whether the lead opening remains constant or varies from the full to the mid gear, the lead angle—or angular distance of the crank from the nearest centre at the moment the port commences to open for the admission of steam—*increases* in magnitude from the full to the mid gear. At this point, if the lead opening = 0, the angular distance becomes = 90°. This condition is of course incompatible with motion, for the port opening being 0, no steam can enter to urge forward the piston; but could this be moved to the 90° or ½-stroke point by sudden independent motion, it would then be repelled by the steam admitted for the support of the return stroke.

VI. To estimate, therefore, the effect of any lead on the continuity of the crank motion, it is necessary to know not only the width of the lead opening (or lead) at the end of the stroke, but also the angular distance of the crank (or lead angle) at the moment lead commenced. In other words, we must know the *area* of the opening and the *time* required to produce it. Thus with a constant lead of $\frac{3}{8}$ inch the port commenced opening for the full gear when the crank was within 10° of the end of the stroke, but for the mid gear when the crank was within $43\frac{1}{2}°$ of the same position, a portion of time nearly $4\frac{1}{2}$ times greater for the same opening.

The relations between travel, lap, lead, and port opening for the different positions F, f^2, f^3, M, b^3, b^2, B of the eccentric, are conveniently illustrated by a diagram, Fig. 205.

Fig. 205.

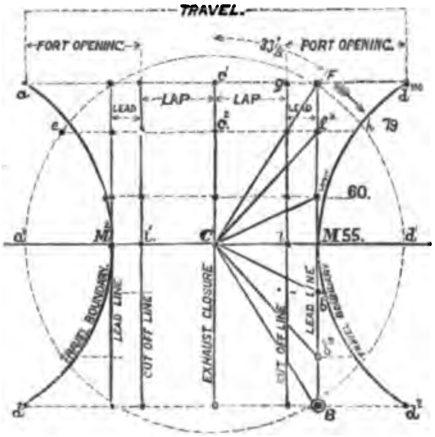
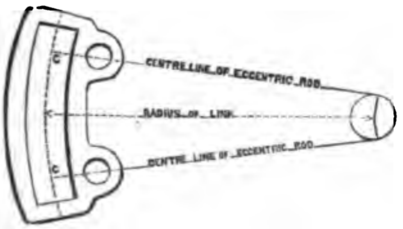


Diagram of an Eccentric's travel-circle in relation to lap, lead, and port opening, at various angles of the Eccentric.

Describe the travel-circle a' F B, lay off on both sides of the centre or exhaust-closure line c' C, the lap and lead, and draw the cut-off and lead lines. Through the various positions F, f^2, etc., draw indefinite lines parallel to the central line of motion a' d'', and upon these lay off on each side of the exhaust-closure line the $\frac{1}{2}$ travel for the position in question. Thus, from c' lay off c' d and c' a each equal to C F the $\frac{1}{2}$ travel; from c^2, c^2 h and c^2 e each equal to C f^2, and so on. Finally, draw the curved lines d M d^2, a M^2 a^2 through the extremities of the travels for their boundary lines. The resulting curves will invariably constitute the branches of an equilateral hyperbola, and thus we obtain a sort of travel scale expressive of the action of the motion at the different gears of the eccentric.

Since for any particular case the lap absorbs a constant portion of the travel, as the distance l l', it is evident that in order to obtain a variable cut-off, we have sacrificed port opening, and consequently the travel in both strokes, and have reduced its excess F d or B d^2 over the lead in the full gears, to *nothing* in the mid gear: those three last diagrams and descriptions are taken from a new American work on valve gears.

Fig. 206.



Geometrical diagram of the formation of the Slotted Link.

Practical Geometry of the Link-Motion.—The first step in this matter is the radius of the link, which, for the slotted form, is produced as shown by Fig. 206. The chord of the arc C, C, is the virtual length of the link or the limit that determine the positions of the eccentric rods and pins in the link which connects them together; this length is of no fixed rule, but may be from twice to thrice the stroke of the eccentric, as desirable with relation to other matters which are explained further on; in the present case the length is three times the stroke. The method of drawing the link as shown is this: First draw a horizontal line termed the radius of the link, which length is agreed on from practical conclusions in connection with the arrangement of the engine—the limits of this length or radius are the centre of the link and that of the crank shaft; from the latter as a centre describe the dotted arc C, C, from the centre of the arc's length; or where it intersects with the radius or horizontal line, set off the points C, C, equidistant; then draw the circle representing the travel of the eccentrics around the centre of the shaft as the centre; draw next tangental lines intersecting at C, C, that represent also the eccentric rod's centre lines when the eccentrics are *loose* on the shaft; set off from C, C, the centres of the pin holes, and thus the geometry of the link is completed; after which the outline is merely a matter of proportion and design.

The "loose" angles of the eccentrics are produced from using the length of the rods as radii intersecting with the travel circle and the pin holes as centres; the length being from the latter to the centre of the shaft, and lines from that point to the intersections represent the angles required for the eccentrics when loose.

The link being drawn, our next step is to describe its application in combination with its connected details, which is shown by Plate A.

The first complete view shows the eccentrics loose on the shaft and connected to the link which is midway hung or suspended on the pin in the lifting rod; this rod is attached at the lower end to a pin belonging to a block that surrounds a screwed rod, as shown in Plate 30. This complete view in Plate A settles also the position of the vertical centre line of the lifting rod, which is, it will be seen, a tangent to the curve or arc of the centre of the link when it and the eccentrics are in the positions represented. This centre line must always be produced as shown, from the law of equilibrium action or the central positions of the several working parts connecting each other, whether a screw-block or a lever is used to shift the link; hence this axiom—the centre line of the lifting rod is a vertical tangent to the central curve of the link when all parts connected are midway situated.

Thus far the position of the lifting rod is the only question settled by the first view, and the next view shows the position of the link when midway, but the eccentrics keyed or *fixed* on the shaft; the link-end of the lifting rod, it will be seen, has shifted a certain distance from the vertical centre line; the crank is horizontal and the eccentrics are at the angles for "lead."

The method of determining those angles is thus:—Describe around the centre of the crank shaft a circle equal in diameter to the travel of the valve, or the radius equal to the throw of the eccentric.

Draw the centre line of the crank at the agreed position; *i.e.*, at an angle or horizontal or vertical; prolonging the centre line through the circle.

At the point of intersection opposite or outside the crank's angle or position, set off a dimension or distance equal to the width of the supply opening caused by the valve minus the lead towards the centre on the centre line; and where that intersects is the starting point to produce the angles of the eccentrics.

From this last intersection—within the eccentric circle—draw a line at right angles to the centre line of the crank, cutting the circle on each side of the line: from those cuttings or points of intersections,

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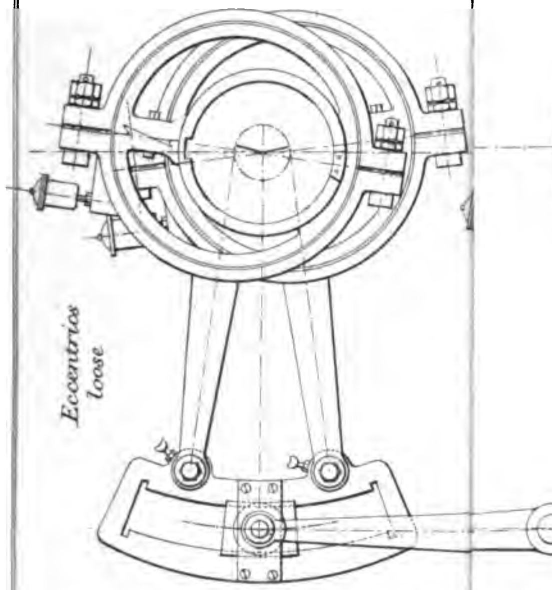
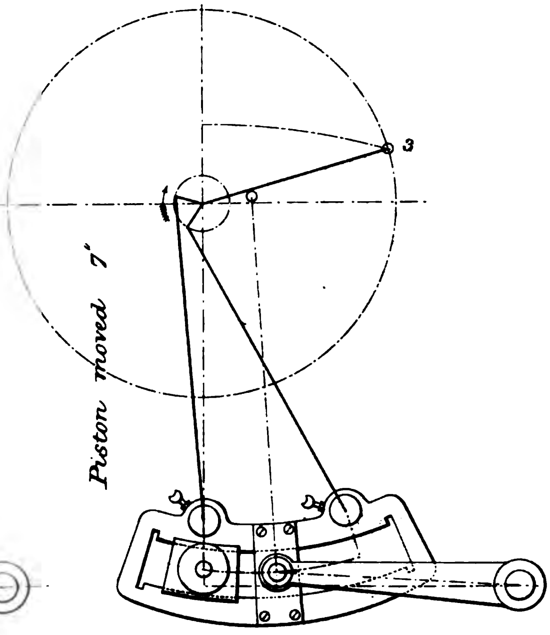
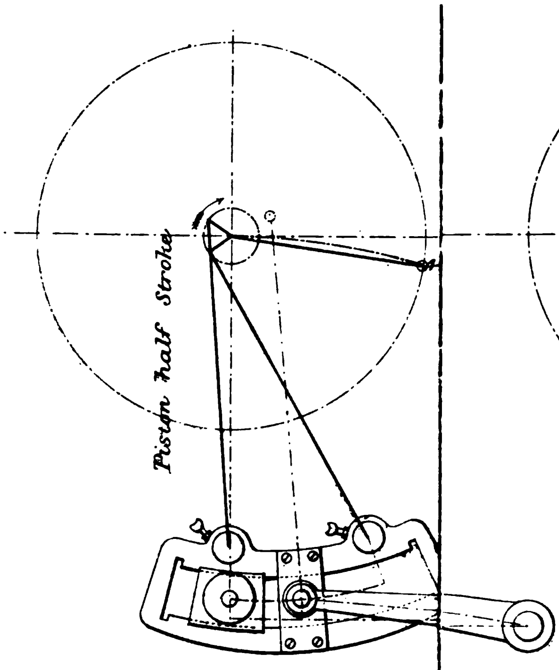


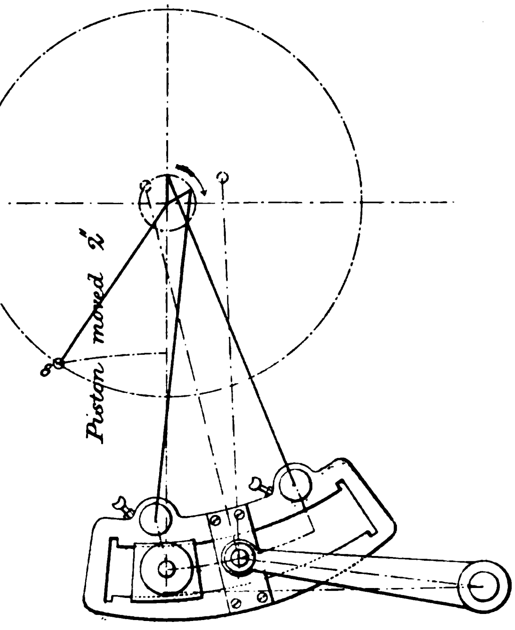
Length of Connecting Rod 4.0 link

Stroke of Piston 2.0 1.3



Lead of Valve 3/16
Width of Steam Opening
caused by Valve 9/16
Outside Lap 3"





Feet

N P. Burgh Direx.

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draw lines to the centre of the circle, which lines are the angles of the eccentrics, and the cuttings their centres of formation at those angles: after which their outlines can be drawn.

Having now determined the angles of the eccentrics, next with their formation-centres as centres, and the length of the eccentric rods as a radius, describe arcs about, and above or below—as agreed on, for the link's position, whether it is up or down or midway—the horizontal centre line. Next with the lifting rod's length as a radius, and its lower end's position as a centre, describe an arc, cutting the vertical centre line of the rod's normal position; referred to before.

Now this *arc* is the leading geometrical feature that demonstrates the action of the link and its position, for every angle of the eccentrics and crank; and when drawing the link-motion, when the eccentrics are shown fixed on the shaft, the draughtsman must always take into consideration that arc *first,* because through it the suspension pin passes forth and back, and in no other path or movement; hence this axiom—the suspension pin of the link always works in an arc, the radius of which is the length of the lifting rod; therefore the greater that length the lesser the vibration of the link up and down.

Knowing now what the centre of the link is subject to in this case, our next step is to explain how to draw it in position, as shown in this figure, which is very simple because the link is midway, and it is merely that the preceding outline is repeated; but when the third figure has to be constructed, or with the link down and the piston at full stroke, the process is very different; being thus:—Repeat the formation of the eccentric circle and angles of the eccentrics; set down the screw-block end of the lifting rod from the normal position equal to the length of the chord of the virtual limit of the link, which is the centre for the radius of the arc, through which the suspension pin moves; draw next constructive arcs, with the eccentric-centres as centres, and the length of the rods as radii, and thus the *central* points of the link are defined. Then all that remains is to practically connect the link, rods, and suspension pin, and to do that *best, trace the link* from either of the two preceding figures, and use the tracing as if the link were actually constructed, lay it on the arcs alluded to, and when the centres of the eccentric rods and suspension pins, all three, fit at once on those arcs, prick their positions through the tracing, after which the outline of the link can be easily drawn as before.

Now there is *no error* with this method because it is the *natural* way of doing it, for all suppositions are omitted, and all actual lengths and circumstances are taken into consideration, exactly as the engine works when constructed, and that is what should be carried out in the drawing office in all cases.

The remainder of the figures in this Plate and the next, B, are all constructed as that just explained; and the last four, illustrate the effect of using a longer link, but all the other limits being constant as before; and direct from that we come to Plate C, which shows not only the two links in various positions, but also the slide valve and cylinder ports of the proportions mentioned all drawn to the same scale as before. Here we have a more direct conclusion illustrated, because we not only see what the link is doing from the action of the eccentrics, but also the action of the slide valve in connection.

To begin with we have drawn the two links midway situated, with the eccentrics keyed for lead and the crank on the horizontal line: we have also divided each "curved limit" of the links into five equal parts, but into four divisions for contrast from the extremities 0, 0, by which means is shown how the valve is effected by the two lengths of links when in those positions; as for example, the short link, when midway, has shifted the valve $\frac{1}{4}$ inch bare from lead, whereas the long link has shifted it $\frac{3}{8}$ inch full from lead: which difference defines the results of a long and short link when the crank is on the horizontal line, or when lead is given by the slide valve. Turning next to the illustration below and the top one on the right hand of this Plate, we see how the valve is situated for lead with the link down: and the two illustrations below this, show that when the links are raised to division 1, the long link has moved the valve from lead $\frac{3}{16}$th inch, but the short link only $\frac{1}{8}$th inch.

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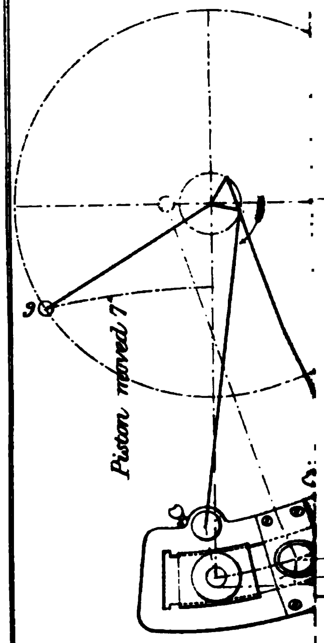
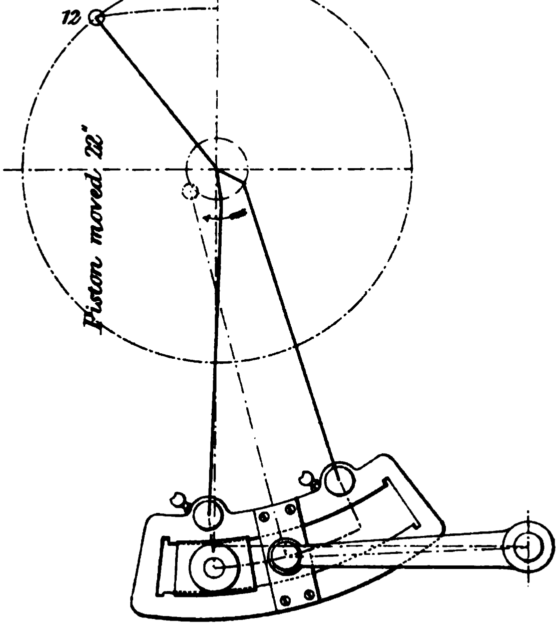
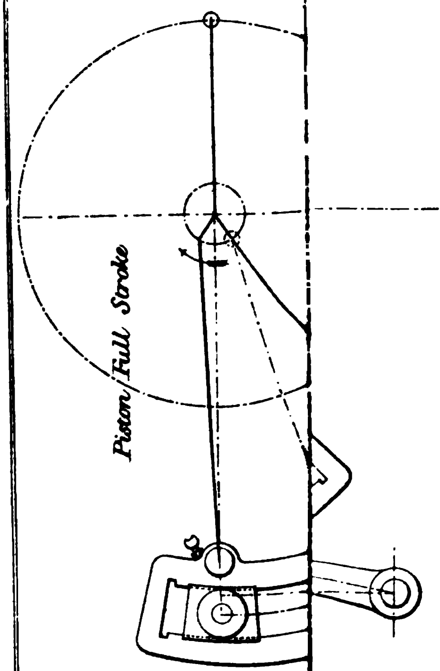


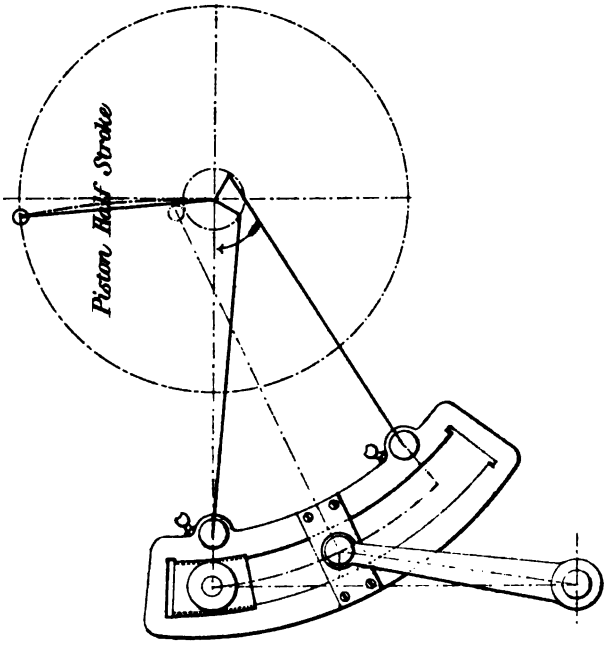


Length of Conne

Stroke of Pisto

Lead of Valve 1/16"
Width of Steam Opening
caused by Valve 9/16"
Outside Lap 3"





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Newbery & Alexander, Lith: 43 Castle St Holborn

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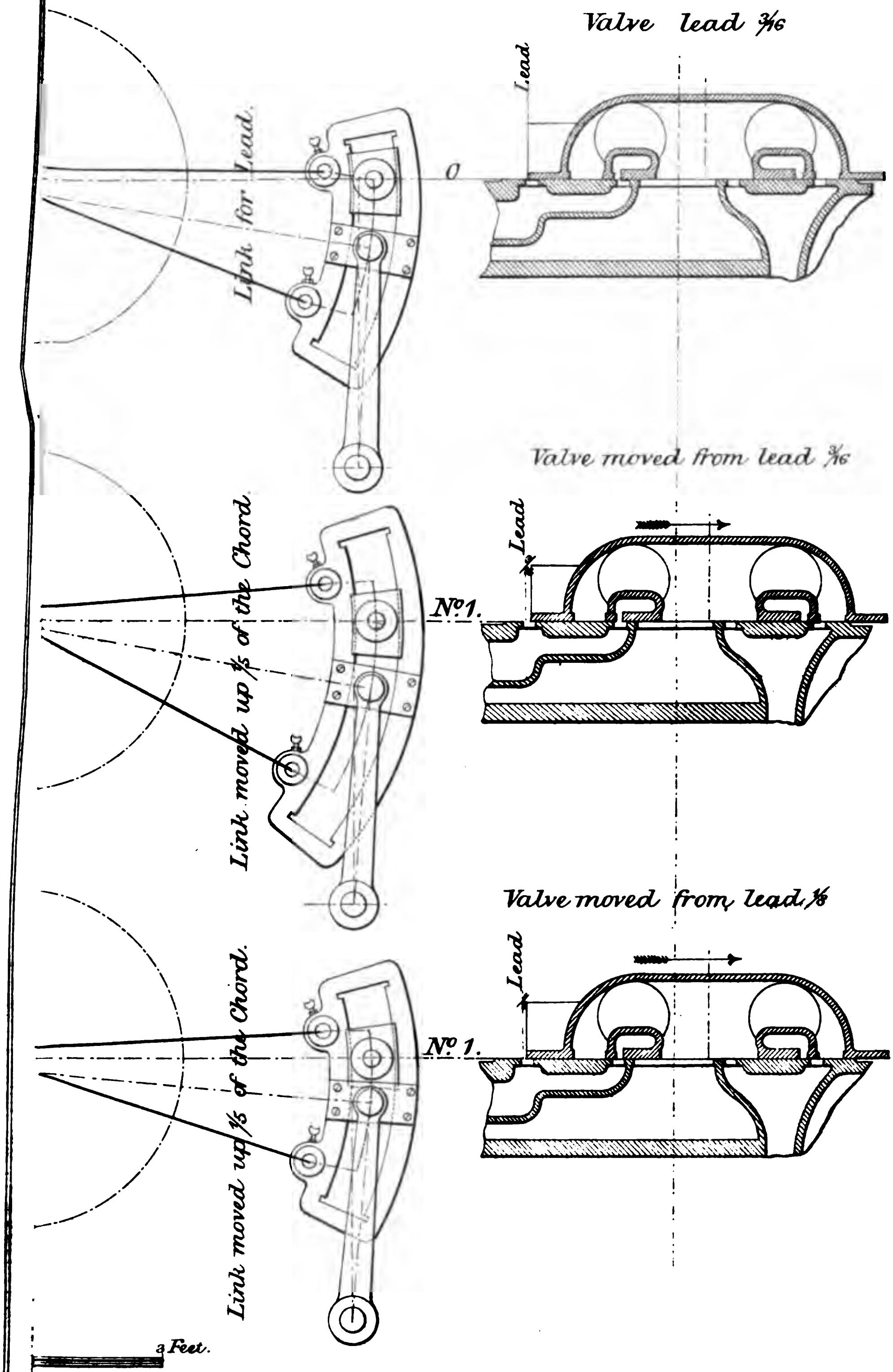
Valve lead 3/16
Lead
Link for Lead.
0
Valve moved from lead 3/16
Lead
Link moved up 1/5 of the Chord.
No 1.
Valve moved from lead 1/8
Lead
Link moved up 1/5 of the Chord.
No 1.
3 Feet.

Newbery & Alexander, lith. 43, Castle St Holborn.

Referring next to Plate D, it will be seen that when the short link is raised to division 2, the valve has moved from lead $\frac{3}{16}$th inch; whereas with the long link in the same position, the valve was shifted $\frac{5}{16}$th inch. The diagrams illustrative of division 3 show the results as similar, because the links are suspended as much above as below the centre line. The same relations occur with the diagrams No. 4, which correspond with those shown by No. 1 on Plate C.

We have from those results this axiom. The length of the virtual limits of the link, when three times the stroke of the eccentric, actuates the valve better than less that length: but beyond that gauge there is no advantage for reversing, starting, or stopping the engine except under exceptional conditions.

Now those conditions are, the length of the eccentric rods, lap of the valve, length of the suspension rod and form of the link; but taking the matter in round numbers for every-day practice the rule given is a constant one for links of the form illustrated.

Of course with links jointed at the extremities the proportion alluded to is entirely thrown out, as the diagram, Fig. 207, illustrates.

Fig. 207.

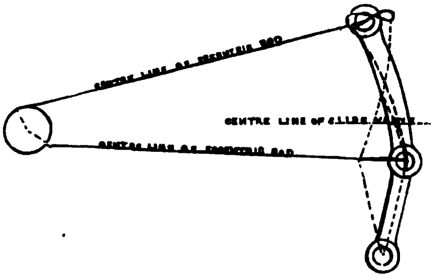
CENTRE LINE OF ECCENTRIC ROD
CENTRE LINE OF SLIDE VALVE
CENTRE LINE OF ECCENTRIC ROD

Diagram showing how the travel of the Valve is reduced from that of the Eccentrics when the Link is jointed at the extremities.

Here it will be seen that the extreme movement of the link on the centre line of the valve's action is reduced, because the eccentrics impart motion to the extremities of the link that are situated *beyond* that line; while at the same time the suspension point is at the lower end of the link instead of at its centre; by which connection, when the link is down only, the most direct action is performed from the eccentric to the valve.

Alluding next to Plate E, it will be seen that the lower half of it contains a series of diagrams, illustrating three examples of link-motion under two conditions of working: those on the left hand are examples showing the differences in the results of suspending the link down and midway, when the crank is horizontal and the eccentrics keyed on the shaft for lead, with three links of separate radii; of two, four, and six feet; proving that the movement of the block is reduced in proportion as the radius of the link is increased.

The diagrams on the right hand illustrate three links of the same radii, with the crank perpendicular and the eccentrics at the same relative angles as before, but the links up and down; showing thereby the relative distances the block-pin will be shifted by those circumstances of movement for the links.

The student has now information sufficient given here to enable him to draw the Geometry of the Link Motion under any circumstance of position and proportion, by remembering the following axioms:—

I. The radius of the link is produced from the distance between the centre of the block and shaft, when the eccentrics are loose on it and the link midway.

II. The length between the centres of the eccentric pins should never be less than twice the stroke of the eccentrics, and need not be more than three times; but the longer the link is proportionately, the more the valve can be shifted, *i.e.*, from the positions when the link is down, to when midway, and from there when the link is up.

III. The shifting of the valve by the raising and lowering of the link is governed mostly by the angles of the eccentrics and position of the crank; as for example, the valve is moved least by the link when the crank is horizontal, and most when it is perpendicular, as shown by Plate E.

IV. The shorter the radius of the link the more readily the valve can be shifted by it, but the greatest strain on the gear is then incurred.

V. Given the positions of the eccentrics, their rods must be used as radii to form arcs, as also must the suspending rod; and, on the eccentric rod arcs, the centres of the link pins rest, with the centre of the suspension pin on its arc also, and thus any position for the link

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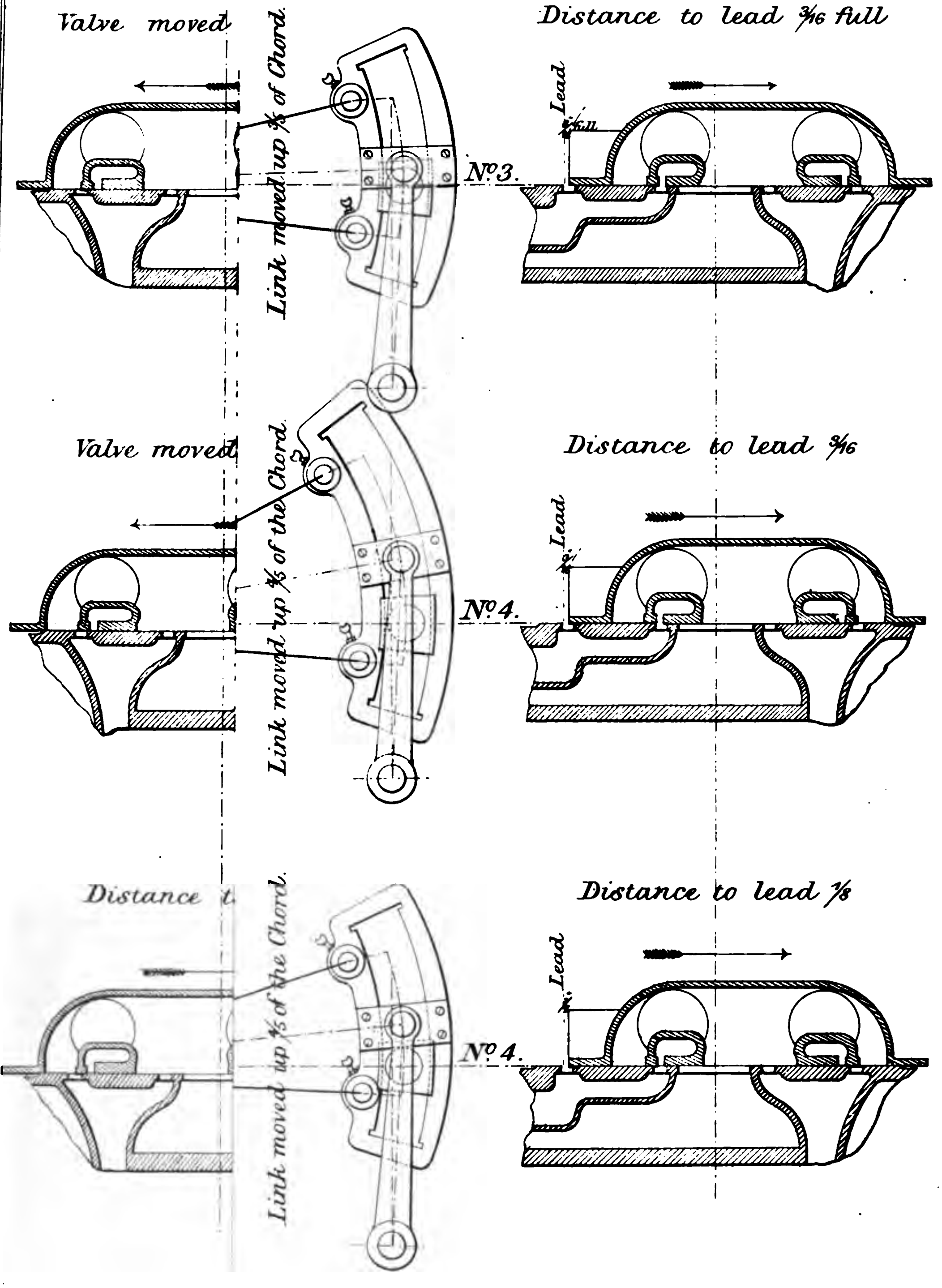
Valve moved
Link moved up 3/8 of Chord.
Distance to lead 3/16 full
Lead
Nº3.
Valve moved
Link moved up 2/5 of the Chord.
Distance to lead 3/16
Lead
Nº4.
Distance t
Link moved up 4/5 of the Chord.
Distance to lead 1/8
Lead
Nº4.

N.P. Burgh. Drax.

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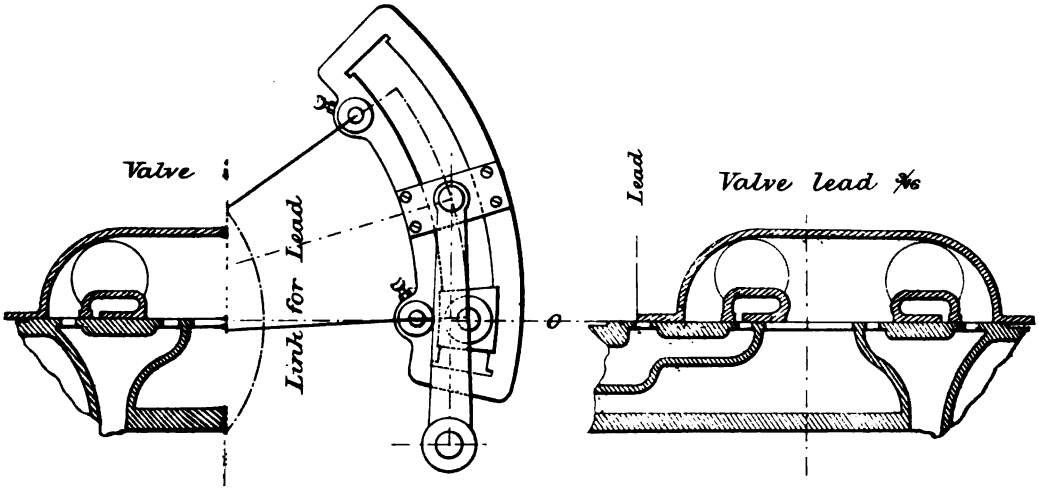
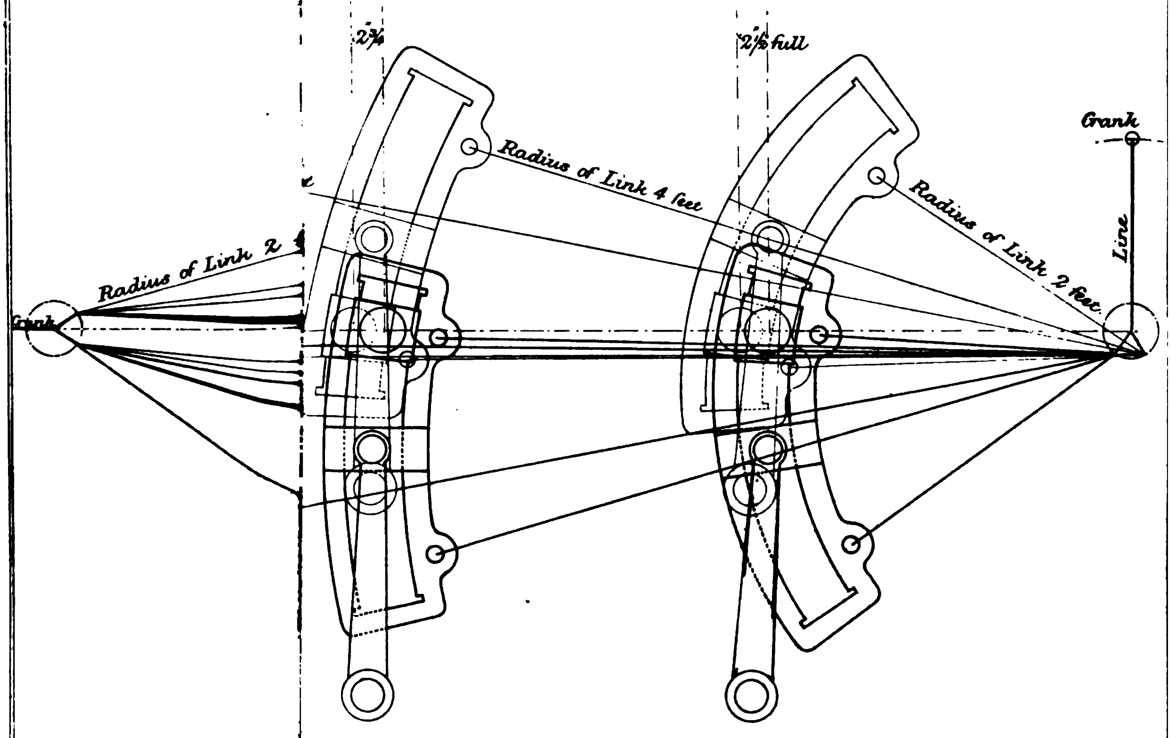
P. BURGH.





KEYED FOR LEAD, CRANK PERPENDICULAR.

N. P. Burgh, Direx

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can be found; always remembering the length of the eccentric rods are equal, and the link's centres are constants.

The application of this method is shown by Plate F, which is the geometrical delineation of the performances of three classes of links; the "common slotted," the "double or single bar," and the "end sliding link;" produced in the following manner.

The eccentric travel circles are divided into twelve equal parts for each eccentric, and numbered respectively, then with the length of the eccentric rods as radii, describe arcs, and number them relatively, draw in the arc of the path of the suspension pin; next, with a tracing of the centres of the link, form the curved figures representing the motions of the two eccentric pins at the ends, and thus the performance of any point in the link can be seen and understood; the geometry of the motion of the "end sliding link" is much the same, with the exception that the lower end moves in a straight line where it is suspended.

For the solid or slotted link, jointed beyond the block at each end, as shown by Fig. 207, on page 209, the method is exactly as explained, so that a repetition is not required.

GEOMETRICAL DELINEATION OF THE ACTION OF A DOUBLE PORTED SLIDE VALVE.—The geometry of this is shown by Plate G, and the method of producing it is thus:—set out on a line the ports and bars belonging to the cylinder in proportion to the dimensions agreed to, and on that line, which is a "face" line, those for the valve when in position for "lead." Next draw the remainder of the valve, if desirable to make that subject clearer, from the face line. Set off as much of the cylinder as requisite to understand that portion, and then draw a limit line, from that line set off the stroke of the piston to the same scale, and draw another limit line parallel with the other, and between those lines "square" and draw the "port" and "bar" lines of the cylinder: bisect the limits and draw a centre line. Next from the "lead" end of the valve set out a distance equal to the travel of the valve and join those points with a semicircle, the centre of which is joined to the "centre line" by the half-travel line; this last intersection is the starting point to construct the geometrical curve of the valve's action; around the point describe a circle equal to the travel of the valve; from the end of the valve draw a line, termed the "lead line;" and where it intersects with the travel circle is the centre of the eccentric for "lead" when the crank is vertical or at full stroke. From that intersection divide the circle into twelve equal parts, and from its centre describe a semicircle representing the half travel of the crank pin, which is divided into six parts, and respectively numbered as shown, with projecting lines above and below the half-travel line, numbered from one to twelve; then as the lead line 1 intersects with the projecting line 1, so will 2 and 2 intersect; 3 and 3, and so on to the end, as illustrated. Next, through those latter intersections, draw the elliptical figure shown by a thick line, and that line represents the proportionate movement of the valve to that of the piston; as for example, when the bars A and B have returned and covered the ports, they cut off the steam, which point is shown to be 39·58 per cent. of the 18-inch stroke and 43·8 per cent. of the 24-inch stroke of the piston; and those bars permit exhaustion at 77·77 and 80·73 per cent. respectively, while the bars C and D move in a corresponding direction and terminate exhaustion at the given points at the other end of the cylinder.

The motive for illustrating two diagrams of two strokes of the piston for the same valve, is to show how the stroke of the piston affects the matter, and to illustrate also what must be understood to enable any one to design a slide valve properly; without which understanding the designer is "working in the dark" and "jumping at results" over which he has no command.

The amount of difference in the points of cut-off for each stroke of the piston are obtained from the proportions of the length of the eccentric and main connecting rods to their respective travels, which has been fully explained at the commencement of this chapter.

Of course the diagrams shown by the plate under notice are produced correctly, while, at the same time, theoretically; but as a practical

THE GEOMETRY OF THE VIBRATIONS OF 3 DIFFERENT LINKS BY N.P. BURGH.

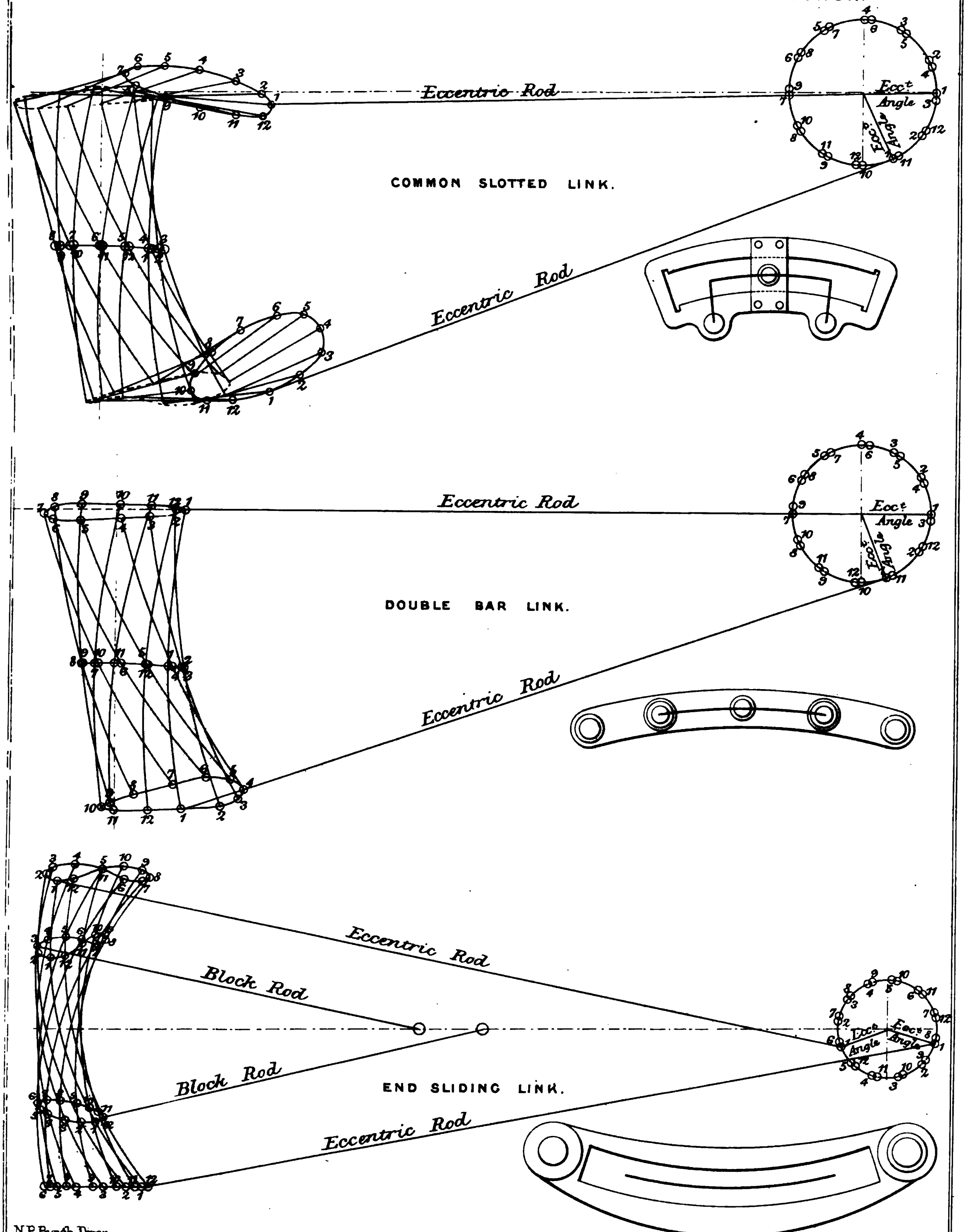

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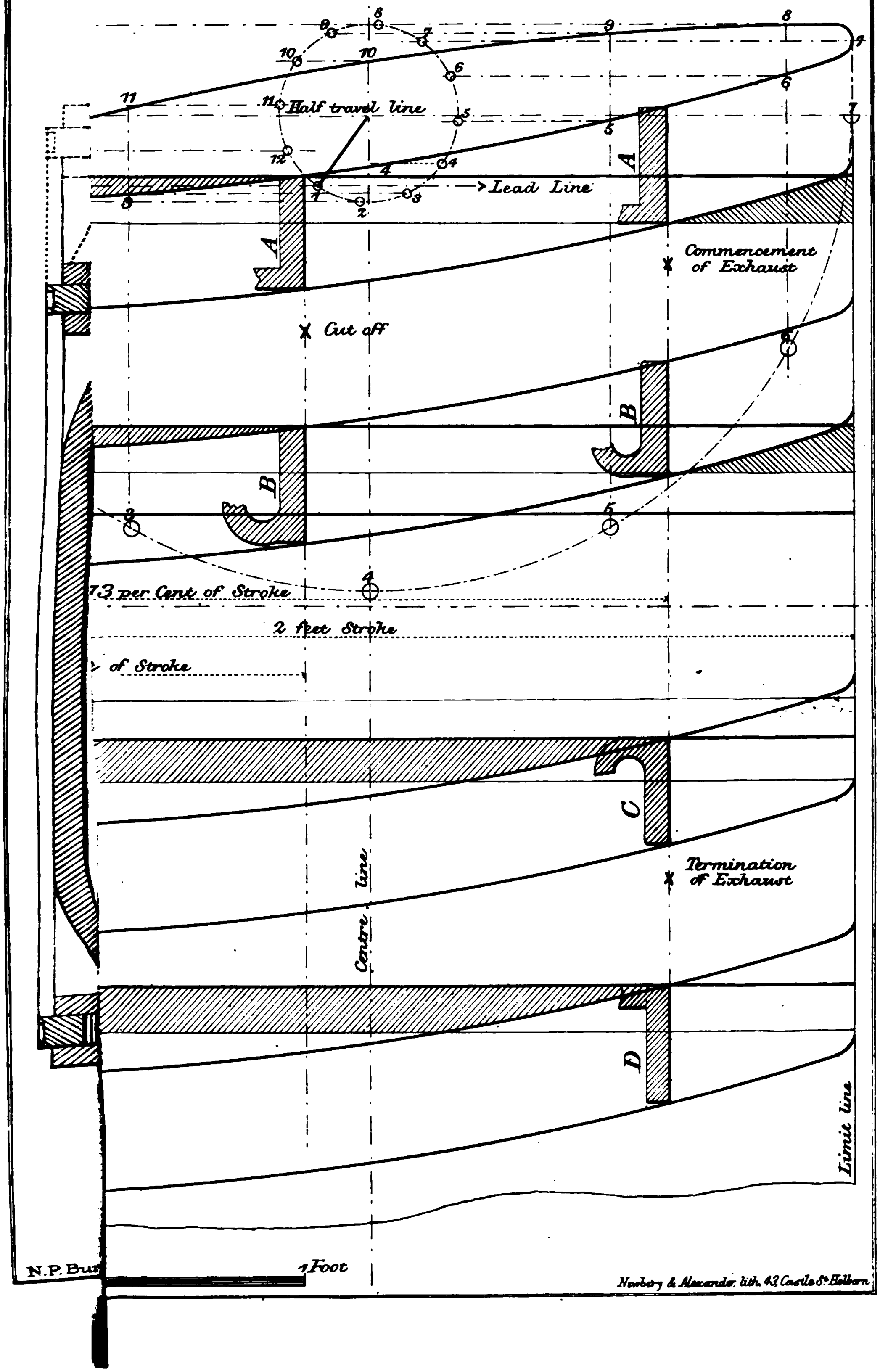
Plate G.

A DOUBLE PORTED SLIDE VALVE BY N.P. BURGH.



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demonstration is always the better, we have introduced the Plate H, which Messrs. James Watt and Co. kindly prepared for this work specially at our request, in order to put this matter in as clear a light as possible. These diagrams are made by an arrangement of mechanism that produces their length to scale as the stroke of the piston and their heights similarly to the stroke of the valve.

The link-motion used is the slotted kind, suspended at the centre and connected within the radial line at each end between the limits of the link as shown. The "cut-off" lines represent the edges of the ports at each end of the cylinder, and the centre line bears the same relation to the "lead" as in our diagram, Plate G. The points numbered 1, 2, 3, and 4, on the cut-off lines, refer to points on the link numbered the same, and show, by their connection, the points of cut-off obtainable with the same valve, link, length of suspension rod, and throw of eccentrics, when the link is down and up to Nos. 1, and raised and lowered to the points 2, 3, and 4, above and below the centre line for ahead and astern duties.

The distances of the points, 1 above and 1 below the centre line in the diagram A from the ends of the same, are very unlike; so much so, that the link, when down for "ahead" movement, permits the cut-off above the centre line at No. 1, to correspond with No. 3 below the centre line and the link up to No. 3, also points 2 and 4 above and below are nearly duplicate in position from their respective limits. There is very little corresponding variation, either with the diagrams for astern motion with the link up at No. 1, and at the points 3 below and with 2 above and 4 below the centre line.

It will be understood, therefore, that the link's positions in all those cases regulate the cut-off by the same valve, and that when we refer to numbers of points of cut-off, they correspond with the numbers of position for the link. Those results refer to eccentric rods six feet long and the link with one foot between centres of pins; and next we come to B diagrams, resulting from the link being one foot six inches long; where the points of cut-off are all later than with A set; although the throw of eccentrics, lap of valve, and lengths of eccentric and suspension rods are constant.

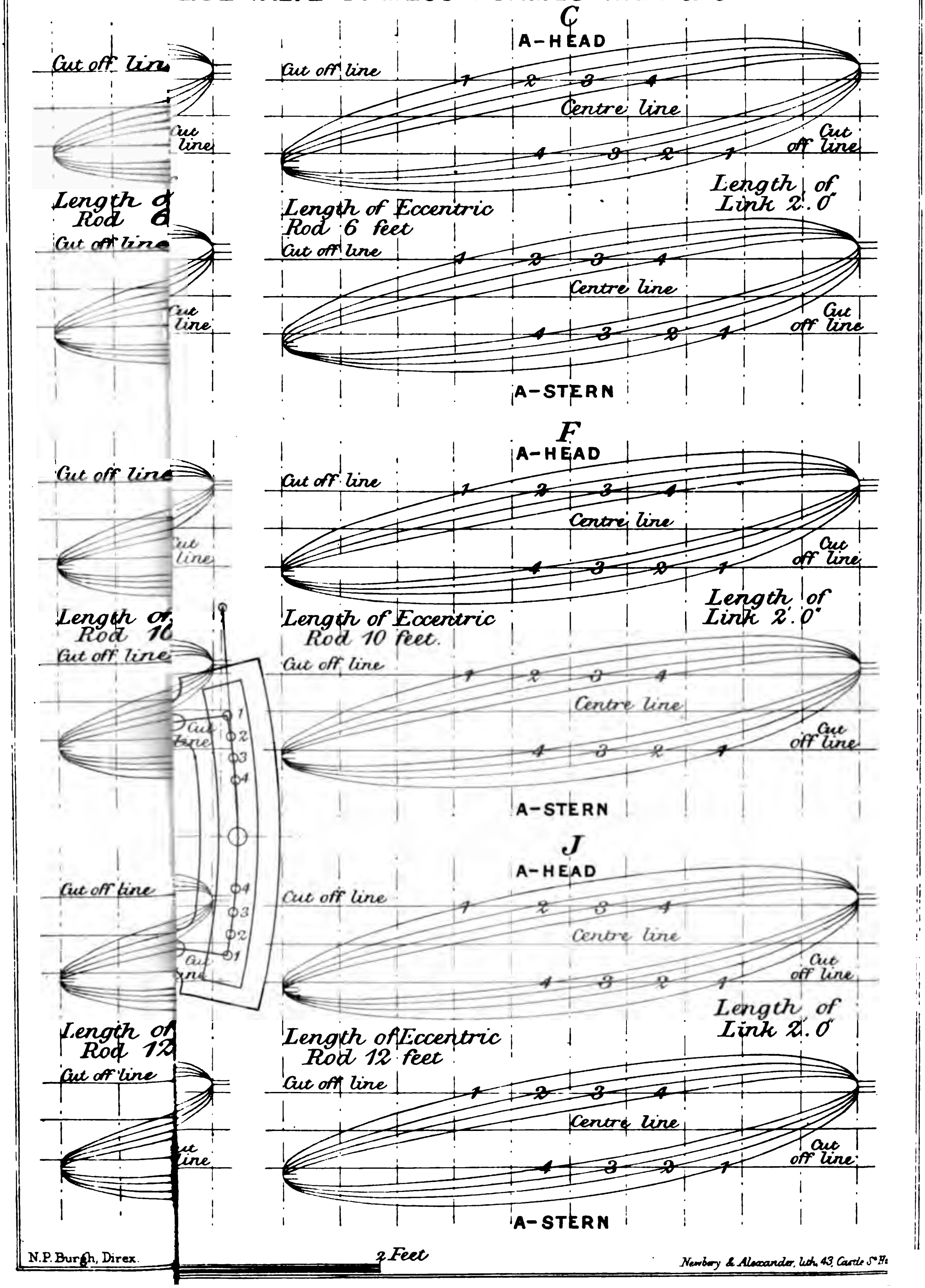
C diagrams are much the best result, because the link is two feet between centres of pins, and the points of cut-off more coincident in position. F diagrams also correspond pretty closely with C, for the link is the same length, but the rods are four feet longer, with the radius of the link similarly lengthened; while J diagrams, with the same length of link, but twice the radius and length of rods, do not duplicate so nearly with C. All the remaining diagrams, of course, correspond in due proportion; but C shows the best result from the proportions given.

We come next to the question of lead, knowing that in general cases, when the link-motion is used as an expansion gear, the earlier the cut-off is by the link's motion, the more lead will be given in proportion to the travel of the valve; or as the link is raised to reduce the travel so is the lead increased.

It will be seen on each of the set of diagrams, at their right-hand ends, there are two *short* lines above the cut-off line above the centre line, and on the left hand two similarly short lines below the other cut-off line, all four projecting towards the right-hand. Now those short lines indicate the points of lead for the Nos. 1 and 4 positions of the link, the other corresponding four having been omitted to prevent confusion. Observe that the lead in diagrams A and C vary very much, and that the lead for No. 4 cut-off is much more in C than in A, showing that the lead is effected mostly in the former case; the variations in the leads in the other examples are less, and also so prominently represented that description is not requisite. It may be added that the minimum lead is $\frac{1}{8}$ inch, and the length of the main connecting rod is thrice the stroke of the piston.

We direct attention next to Plates 64 and 64A, which illustrate the performances of link-motions and slide-valves of locomotive engines so completely, that our explanation of the principles in Plate C apply generally here also; these plates have the addition of tabular statements of the "workings" of the links and valves so fully explanatory,

SLIDE VALVE BY MESSRS JAMES WATT & Co



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that description is really unnecessary; but perhaps it will be well to point out the main features for the benefit of students, taking first Plate 64 into notice. The slide-valve is shown at the position for lead, and the points on the port line numbered 1 to 8, are the points of cut-off, while those above, relating to the *inside* edge of the valve, refer to the corresponding points of exhaustion: this plate is in itself the most perfect explanation of the duty of a slide-valve that can be; and the profession owes much to Mr. Berkley for his kindness in permitting it to appear here; the same acknowledgment applies also to the other Plate 64A, which is equally useful and easily to be understood.

We notice next the performances of the "straight" link-motion, as shown by Plate 56, the arrangement of which is, that, on the reversing shaft A are forged two arms B and C, on opposite sides of the shaft, the front arm B being connected with the valve rod D, and the back arm C with the link E, by means of suspending or sustaining links in the ordinary manner. As the arms B and C are on opposite sides of the reversing shaft, the vertical movements given to the valve rod, with the link block at its extremity, and to the link are in opposite directions; and their simultaneous movements, but in opposite directions, compensate for the curvature of the ordinary link, and consequently a straight link is substituted, the construction of which is simpler than that of the curved link.

The front arm B of the reversing shaft is made longer than the back one C, in such a proportion that, for any motion of the reversing shaft, the link E and the eccentric rods move through 3-5ths of the vertical space described at the same time by the link block and the valve rod D. On moving the gearing out of the position of midgear, shown in the figures, into the position of full forward gear, the link block moves upwards through a distance of 2½ inches, the effect of which is to give the valve rod an obliquity that is equivalent to shortening it up 1-10th inch. But at the same time the link moves downwards through a space of 1½ inch, and the obliquity of the forward eccentric rod F is thus diminished to an extent that is equivalent to lengthening it out

1-10th inch. Thus the shortening of the valve rod is exactly compensated for by the lengthening of the eccentric rod, and the valve will consequently remain stationary, causing the lead to be unaltered. Similarly, when the engine is thrown into the position of full backward gear, the same compensation takes place between the valve rod and the backward eccentric rod G, and the valve remains stationary. In order that the lead may remain constant in the same manner in the intermediate positions of gear, the correct form of the link ought to be two equal curves, concave towards the valve rod, having their extremities in the same straight line with the centre of the link, the curvature amounting to not more than about 1-32nd inch, for the dimensions of gearing as shown. The error arising from making the link straight, instead of curved in the above manner, causes therefore a total variation of not more than 1-32nd inch in the lead of the valve, and the lead may therefore be considered practically constant, at the same time that the straight form of link has an advantage in simplicity of construction, and more especially in facility of repairs.

The vertical movement of the link being 3-5ths of that of the link block, the total vertical movement of the link in reversing is therefore only 3-8ths of that in the shifting link motion; and the vertical movement of the valve rod and link block is 5-8ths of that in the stationary link motion; the length of the reversing lever is thus proportionately greater. The arrangement of the single rectangular bar link-motion, shown in the plate, is very simple, it being one bar to which the eccentric rods are connected, the sliding block encloses the part of the link it fits on, with a back-plate and set-screw for adjustment. The next arrangement consists of two bars of the same shape, connected by set-plates, bolts and nuts. The block fits between the bars, and is formed with flanges to ensure steadiness of position at any point. The box-link arrangement is formed with two bars, so shaped that, when connected, the block is enclosed by them, with an opening back and front for the rod to pass through. The diagrams show the working of this motion and slide valve as illustrated, in connection with the following table.

Distribution of Steam by Straight Link-Motion.

Stroke of Piston .	24 inches.	Inside Lap . .	Line and line.
Common Slide Valve		Steam Ports . .	$1\frac{3}{8}$ inch × 12 inches.
Outside Lap . .	1 inch.	Exhaust Port . .	$2\frac{1}{2}$ inches × 12 inches.

Number of Notch.		Lead of Slide.		Travel of Slide.	Total Opening of Slide to Steam.		Point of Cutting off.		Exhaust opens and Compression begins.		Period of Expansion.		Period of Compression.	
		Front Stroke.	Back Stroke.		Front Stroke.	Back Stroke.	Front Stroke.	Back Stroke.	Front Stroke.	Back Stroke.	Front Stroke.	Back Stroke.	Front Stroke.	Back Stroke.
		Inches.	Inches.	Inches.	Inches.	Inches.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Forward Gear .	7	$\frac{5}{16}$	$\frac{5}{16}$	$4\frac{1}{2}$	$1\frac{1}{8}$	$1\frac{3}{8}$	75	72	91	90	16	18	9	10
	6	$\frac{5}{16}$	$\frac{5}{16}$	4	$\frac{7}{8}$	$1\frac{1}{8}$	68	67	89	87	21	20	11	13
	5	$\frac{5}{16}$	$\frac{5}{16}$	$3\frac{3}{4}$	$\frac{3}{4}$	1	63	63	87	85	24	22	13	15
	4	$\frac{5}{16}$	$\frac{5}{16}$ bare	$3\frac{5}{16}$	$\frac{5}{8}$	$\frac{13}{16}$	55	56	84	81	29	25	16	19
	3	$\frac{5}{16}$	$\frac{5}{16}$ bare	$3\frac{1}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	44	46	80	77	36	31	20	23
	2	$\frac{5}{16}$	$\frac{1}{4}$ full	$2\frac{13}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	31	34	73	70	42	36	27	30
	1	$\frac{5}{16}$	$\frac{1}{4}$ full	$2\frac{11}{16}$	$\frac{5}{16}$	$\frac{3}{8}$	21	23	65	61	44	38	35	39
Mid Gear	0	$\frac{5}{16}$	$\frac{1}{4}$	$2\frac{9}{16}$	$\frac{5}{16}$	$\frac{1}{4}$	10	10	50	46	40	40	50	54

The Cutting off, Exhaust, Expansion, and Compression, are given in per centages of the stroke of the piston. The Lead is set equal in forward and backward full gear. The Front Stroke is from the buffer plank towards the firebox. The Fore Eccentric Rod is coupled to the bottom of the link.

RULES.

Slotted Link-Motion.

Area of slide block pin = area of valve rod × 1·25.

Sectional area of each bar of link (square) = area of valve rod × 2.

Thickness of block beyond pin's diameter = $\frac{\text{pin's diameter}}{5 \text{ to } 7}$

Thickness of flanges of block = $\frac{\text{pin's diameter}}{7 \text{ to } 9}$

Length of sliding block = diameter of pin × 2·5.

Distance between centres of eccentric rod's pins = stroke of slide valve × 2·5 to 3.

Area of eccentric pin = area of slide valve rod × 1· to ·875.

Area of eccentric rod at centre = area of slide valve rod.

Width of eccentric rod at link end = diameter of pin × 1·25.

Taper of eccentric rod = $\frac{1}{4}$ to $\frac{3}{8}$ inch per foot in length.

Area of securing bolts to eccentric band = area of valve rod × ·7 to ·6.

Thickness of T head = diameter of securing bolts.

Solid Link.

Area of solid link = area of slide valve rod × 2·7 to 2·5.

Thickness of link = diameter of valve rod × 1·25.

Length of sliding block = width of link × 1·5.

Thickness of block, front, back, and sides = width of link × ·3 to ·2.

Diameter of projections = diameter of valve rod.

Length of projection = diameter of projection × ·7 to ·6.

Width of portion secured to valve rod = diameter of projection × 2.

Diameter of securing studs (3) =

$$\frac{\text{diameter of slide valve rod}}{2 \text{ to } 3}$$

Eccentric, Bands, Rods, Bolts, &c.

Diameter of valve rod = diam. of piston rod × ·4.

Area of solid link pin = area of valve rod × ·7 to ·8.

Area of band bolts = area of pin × ·75.

Width of band = nut across angles × 1·03.

Thickness of boss of eccentric =

$$\frac{\text{diameter of crank shaft}}{6 \text{ to } 8}$$

Thickness of rim and arms = thickness of boss × ·75.

$$\text{Depth of recess} = \frac{\text{rim thickness}}{4 \text{ to } 5}$$

Width of rim, arms, and boss – depth of recess × 2 + width of band.

Thickness of band, wrought iron = diameter of bolts × ·6, gun metal × ·75.

Thickness of internal brass hoop = thickness of band × ·2.

Width of projection = width of band × ·4.

Diameter of eye of rod = that of pin × 2.

Width of eye = width of solid link × ·5.

Area of eccentric rod at eye = area of valve rod × ·8.

Width of rod = diameter of pin × 1·8.

Taper = ½ inch per foot.

$$\text{Thickness at eye} = \frac{\text{area}}{\text{width}}$$

Thickness at band = thickness at eye × 1·5.

Thickness of bolt flange = diameter of bolts.

Starting or Reversing Gear.

Diameter of wheel at centre of handles = 2 feet 6 to 3 feet 6 inches.

Height of centre of handle from starting platform = 3 feet 6 inches.

Length of handles = 4½ to 6 inches.

Diameter of handles at neck = 1 inch.

Diameter of handles at extremity = 1¼ to 1⅜ of an inch.

Diameter of bosses for handles = diameter of handle at neck × 2.

Thickness of rim of wheel = diameter of handle bosses.

Depth of rim = thickness of rim × ·75.

Width of arm at rim = depth of rim.

Taper of arm ¼ inch per foot.

Diameter of wheel shaft = diameter of slide valve rod.

Diameter of boss for shaft = diameter of shaft × 2.

Diameter of weigh shaft of spur segment = diameter of wheel shaft × 1·25.

When two starting wheels are used the area of each shaft = the area for 1 wheel × ·75.

Ratio of pinion or worm to segment = 4 or 6 to 1.

Pitch of teeth in inches = diameter of slide valve rod × ·8 to ·5, using the latter for the greater ratio.

Pitch of teeth of mitre wheels (gun metal) = diameter of valve rod × ·4 to ·3.

Diameter of screw rod = diameter of slide valve rod × 1·4 to 1·25.

Width of sliding block = diameter of screw rod × 1·5.

Length of sliding block = diameter of screw rod × 2.

Pitch of screw = diameter of screw.

Diameter or area of link connecting rod = that of valve rod.

Diameter of lever weigh shaft = diameter of slide valve rod × 1·5 to 2.

REVIEW.—We have thought it best to conclude this work with a review of what has been done in it, rather than do that in the preface; knowing that the preface is always looked at by charlatan critics as the field from which they reap their harvest of technical language, when reviewing a work they can never understand; which, while doing, is done with an illegitimate air of profound wisdom, so that the general reader may be deceivingly refreshed with the apparent draught of superior knowledge poured out to him. In another way, an empty critic will find fault with everything, and ridicule the best portion that has cost the most time and trouble to produce, without even offering any suggestion; and the conceit with this vacancy of knowledge is founded on the delusion that all critics are infallible, while it really happens often that the reviewer of a work knows very little of the subject, and from that ignorance condemns it mechanically.

We commenced this work with the "History of the Invention of the Link-Motion," and having settled that question, the next subject we explained is "The Principles of the Action of Steam-Working Valves;" those are fully investigated for the benefit of the student, so that he can understand—if he will—the meaning of the words, lead, cut-off, expansion, and exhaustion. The two former terms relate to the valve, but the latter to the steam; in the same chapter also is treated, at some length, the action of one volume of steam in the cylinder.

Our next chapter is a matter of history combined with remarks of a practical nature, bearing directly on the efficiency of any example dilated on. One great historical truth may be mentioned also, it is, that there has been no improvement in the link-motion since the year 1843, and that every conceivable form of link and connections have been carried out since then to displace the original arrangement. Expansion gears have had their share of attention too, but for moderate speeds, nothing yet has been introduced that supersedes the cam-motion of 1821; for the shape of the cam can be made to work the valve quickly and slowly in the same revolution, which the eccentric does not perceptibly do. Valves, of course, put in, as it may be, a warlike appearance against the gear, under the direction that the gear might be imperfect, but the valve was not, and thus one advantage was gained at least; the rule there being; cut-off by the valve's design, and not by the motion of the gear; as, for example, in many cases *three* faces were introduced, all in working contact; all to be kept steam-tight, and all said to be required for one operation. It is but fair to our leading firms to say they have kept out of those extreme measures; following rather the dictates of common sense than "airy" conclusions.

The practical method of treating all mechanical arrangements—and valves and gear in particular—is to prepare for "wear and tear," for when that is omitted the downfall of the proposition soon follows as a matter of course.

The best kind of slide valve for general duties is the double ported equilibrium; packed at the back with a ring the same size and shape in outline as the face limits.

The most perfect link-motion yet introduced is the arrangement with the eccentric rod pins in the centre of the link's width; and when the link is up or down, that point is the centre of the block-pin; by which means the vibration is the least, and always equal—up or down—when the link is suspended at the centre of its length and width.

The present favourite expansion gear is the eccentric and slotted lever, in connection with a "gridiron" or multiple-ported valve.

Starting or reversing gears have not improved much since the year 1862; whether they are worked by steam or hand power; at the present period the vertical screw rod and sliding block on it seems to be the best for raising and lowering the link; because of the straight motion in the place of the arc described by a lever pin as in the old arrangements.

In conclusion our endeavour has been in this work to make it valuable—not from our performance in it—but rather from the facts we have presented, as a standard of reference to refresh the memory as well as to instruct the mind.

N. P. B.

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53. Arrangement of Flat Slide Valves, Separately Situated for the Supply and Exhaustion of the Steam and Governor Gear, to regulate the Cut-Off. By Messrs. J. and E. Wood.
54. Elevations of the Engine shown by Plate 53. By Messrs. J. and E. Wood.
65. Arrangements of Expansion Slide Valve, and Variable Gears for Stationary Engines.

MARINE EXPANSION GEARS.

20. Arrangement of Expansion Gear for Engines of 160 H. P., as fitted for the R. S. N. Co. By Messrs. J. Penn and Sons.
24. Expansion Gear of the Engines fitted in S.S. "Neera," 180 H. P. nominal collectively. By R. and W. Hawthorn.
25. Expansion Gear of the Engines fitted in S.S. "Orphee" 45 H. P. nominal collectively. By R. and W. Hawthorn.
26. Expansion Gear of the Engines fitted in W. S. M. S. "Columbian," 300 H. P. nominal collectively. By Mr. C. W. Jaffrey, for Thomas Richardson and Sons.
28. An Arrangement of Expansion Gear. By Mr. C. W. Jaffrey.

No.
33D. Expansion Gear for Oscillating Engines. By Messrs. Maudslay, Sons, and Field.
33E. General Cam-Expansion Gear for Oscillating Paddle-Wheel Engines, 250 H. P. nominal collectively, 1870.
34. Arrangement of Expansion Gears as fitted by Messrs. Ravenhill, Hodgson, and Co.
35. Arrangement of Expansion Gears as fitted by Messrs. Ravenhill, Hodgson, and Co.
36. Arrangement of Expansion Gear for Marine Screw Engines, as used in the year 1870.
37. Expansion Valves and Gear for Screw Engines.
37A. Expansion Gear fitted in S.S. "Abden," 500 H. P. nominal collectively. By Mr. John Key, Kirkcaldy.
38. Revolving, Seating, and Stationary Cylindrical Expansion Gear. By James Watt and Co.
39. Arrangement of Expansion Gear fitted in S.S. "Charkieh and Dakalieh," 350 H.P. nominal collectively. By Messrs. J. and G. Rennie.
39A. Expansion Gear fitted in H.M.S. "Collingwood," 400 H. P. nominal collectively. By Messrs. J. and G. Rennie.
39B. Arrangement of Expansion Gear and Valve for Vertical Inverted Engines, 200 H.P. nominal collectively. By Messrs. J. and W. Dudgeon.
39C. Spur Wheel Valve Gear for Three Cylinder Screw Engines of 700 H.P. nominal collectively. By Messrs. Maudslay, Sons, and Field.

MARINE REVERSING GEAR.

1. Reversing Gear of the Engines fitted in H.M.S. "Arethusa," 500 H. P. nominal collectively. By Messrs. John Penn and Son.
2. Reversing Gear of the Engines fitted in H.M.S. "Northumberland," 1,350 H. P. nominal collectively. By Messrs. John Penn and Sons.
3. Portion of Reversing Gear of the Engines fitted in the S.S. "Roma and Venetia," 900 H. P. nominal collectively. By Messrs. Maudslay, Sons, and Field.
4. Portion of Reversing Gear fitted to Engines 400 H. P. nominal collectively. By Messrs. Humphrys and Tennant.
5. Portion of Reversing Gear of the Engines fitted in the Turkish Frigate "Sultan Mahmoud," 900 H. P. nominal collectively. By Messrs. Ravenhill, Hodgson, and Co.
6. Reversing Gear of the Engines fitted in H.M.S. "Enterprise," 160 H.P. nominal collectively. By Messrs. Ravenhill, Hodgson, and Co.
7. Reversing Gear fitted in the Royal Mail S.S. "Rushine." Twin Screw Engines, 350 H. P. nominal collectively. By Messrs. J. and W. Dudgeon.
8. Reversing Gear fitted in the S.S. "Mary Augusta." Twin Screw Engines, 300 H. P. nominal collectively. By Messrs. J. and W. Dudgeon.
9. Portion of Reversing Gear of the Engines fitted in H.M.S. "Research," 200 H. P. nominal collectively. By Messrs. James Watt and Co.
10. Portion of Reversing Gear fitted in S.S. "Medusa and Triton." Twin Screw Engines, 200 H. P. nominal collectively. By Messrs. James Watt and Co.
11. Reversing Gear of the Engines, 70 H. P. nominal collectively. By R. Napier and Sons.
13. Steam and Hand Reversing Gear of the Engines fitted in S.S. "Periere" and "Ville de Paris," 800 H. P., nominal collectively. By Messrs. R. Napier and Sons.
16. Portion of the Steam and Hand Reversing Gear of the Engines fitted in H.M.S. "Hector," 800 H. P. nominal collectively. By Messrs. R. Napier and Sons.
17. Reversing Gear of the Engines fitted in the Danish Armour-Cased Cupola Iron Ship, "Rolf Krake," 235 H. P. nominal collectively. By Messrs. R. Napier and Son.
22. Reversing gear fitted in H.M.S. "Abyssinia," 200 H. P. nominal collectively. By Messrs. J. and W. Dudgeon.
23. Reversing Gear of H.M.S. "Spartan." By Messrs. J. and G. Rennie.
24. Reversing Gear of the Engines fitted in S.S. "Neera," 180 H. P. nominal collectively. By R. and W. Hawthorn.
25. Reversing Gear of the Engines fittted in S.S. "Orphee," 45 H. P. nominal collectively. By R. and W. Hawthorn.
29. Reversing Gear of the Steeple Engines fitted in S.S. "Falkland." By Messrs. Maudslay, Sons, and Field.
30. Reversing Gear of Twin Screw Engines, 200 H.P. nominal collectively, fitted in S.S. "R. N." By N. P. Burgh.
32. Reversing Gear for Link Motion or Twin Screw Engine fitted in S.S. "R. N.," 200 H. P., nominal collectively. By N. P. Burgh.

No.
33A. Reversing Gear for Oscillating Paddle-Wheel Engines of 250 H. P. nominal collectively, 1870.
33B. Reversing Gear of Oscillating Engines of 200 H.P. nominal collectively. By Messrs. J. and W. Dudgeon.
33C. Reversing Gear for Oscillating Engines, 120 H.P. nominal collectively. By Messrs. James Watt and Co.
37A. Reversing Gear fitted in S.S. "Abden," 500 H. P. nominal collectively. By Mr. John Key, Engineer, Kirkcaldy.
39C. Spur Wheel Valve Gear for Three Cylinder Screw Engines of 700 H. P. nominal collectively. By Messrs. Maudslay, Sons, and Field.
47. Reversing and Starting Gear. By J. F. Spencer.

MARINE LINK-MOTION.

1. Link-Motion of the Engines fitted in H.M.S. "Arethusa," 500 H. P. nominal collectively. By Messrs. John Penn and Sons.
2. Link-Motion of the Engines fitted in H.M.S. "Northumberland," 1350 H. P. nominal collectively. By Messrs John Penn and Sons.
3. Link-Motion of the Engines fitted in the S.S. "Roma" and "Venetia," 900 H. P. nominal collectively. By Messrs. Maudslay, Sons, and Field.
4. Link-Motion fitted to Engines, 400 H. P., nominal collectively. By Messrs. Humphrys and Tennant.
5. Link-Motion of the Engines in the Turkish Frigate "Sultan Mahmoud," 900 H. P. nominal collectively. By Ravenhill, Hodgson, and Co.
6. Link-Motion of the Engines fitted in H.M.S. "Enterprise," 160 H. P. nominal collectively. By Messrs. Ravenhill, Hodgson, and Co.
7. Link-Motion fitted in the Royal Mail S.S. "Ruahine," Twin Screw Engines, 350 H. P. nominal collectively. By Messrs. J. and W. Dudgeon.
8. Link-Motion fitted in the S.S. "Mary Augusta." Twin Screw Engines, 300 H. P. nominal collectively. By Messrs. J. and W. Dudgeon.
9. Link-Motion of the Engines fitted in H.M.S. "Research," 200 H. P. nominal collectively. By James Watt and Co.
10. Link-Motion fitted in S.S. "Medusa and Triton," 200 H. P. nominal collectively. By James Watt and Co.
11. Link-Motion of the Engines, 70 H. P. nominal collectively. By R. Napier and Sons.
12. Link-Motion of the Engines, 70 H. P. nominal collectively. By Messrs. Napier and Sons.
13. Portion of Link-Motion of the Engines fitted in S.S. "Perière" and "Ville de Paris," 800 H. P. nominal collectively. By Napier and Sons.
14. Link-Motion of the Engines fitted in S.S. "Perière" and "Ville de Paris," 800 H. P. nominal collectively. By Napier and Sons.
15. Main details of the Link-Motion of the Engines fitted in S.S. "Perière" and "Ville de Paris," 800 H. P. nomimal collectively. By Napier and Sons.
16. Link-Motion of the Engines fitted in H.M.S. "Hector," 800 H. P. nominal collectively. By Napier and Sons.
17. Link-Motion of the Engines fitted in the Danish Armour-Cased Cupola Iron Ship, "Rolf Krake," 235 H.P. nominal collectively. By Messrs. R. Napier and Sons.
18. Link-Motion fitted in S.S. "Edinburgh." Inverted Compound Engines, 250 H.P. nominal collectively. By Messrs. Laird Brothers, Birkenhead.
19. Link-Motion of the Engines fitted in S.S. "Dublin," 70 H.P. nominal collectively. By Courtney, Stephens, and Co., Dublin.
20. Arrangement of Link-Motion for Engines of 160 H. P., as fitted for the R. S. N. C. By Messrs. J. Penn and Sons.
21. Modern Solid Link-Motion. By Messrs. Humphrys, Tennant, and Co., 1870.
22. Link-Motion fitted in H.M.S. "Abyssinia." Twin Screw, 200 H.P. nominal collectively. By. J. and W. Dudgeon.
23. Link-Motion of H.M.S. "Spartan." By J. and G. Rennie.
24. Link-Motion of the Engines fitted in S.S. "Neera," 180 H.P. nominal collectively. By. R. and W. Hawthorn.
25. Link-Motion of the Engines fitted in S.S. "Orphee," 45 H.P. nominal collectively. By R. and W. Hawthorn.
26. Link-Motion of the Engines fitted in W.I.M.S. "Columbian," 300 H. P. nominal collectively. By G. W. Jaffrey, for Thomas Richardson and Sons.
27. Adjustable Link and Connections of the Engines fitted in W.I.M.S. "Columbian."
28. An Arrangement of Expansion Gear. By. Mr. G. W. Jaffrey.
29. Link-Motion of the Steeple-Engine fitted in S.S. "Falkland." By Maudslay, Sons, and Field.
30. Link-Motion of Twin Screw Engines, 200 H. P. nominal collectively, fitted in S.S. "R. N." By N. P. Burgh.

No.
31. Details of Link-Motion of Twin-Screw Engines fitted in S.S. "R.N.," 200 H.P. nominal collectively. By N. P. Burgh.
32. Details of Reversing Gear for Link-Motion of Twin-Screw Engines fitted in S.S. "R.N.," 200 H. P. nominal collectively. By N. P. Burgh.
33. Link-Motion for Engines, 400 H. P. nominal collectively, having a solid link and central connection for the Eccentric Rods. Invented by N. P. Burgh, in the year 1862.
33B. Arrangement of Link-Motion of Oscillating Engines of 200 H. P. nominal collectively. By Messrs. J. and W. Dudgeon.
33C. Link-Motion for Oscillating Engines, 120 H. P. nominal collectively. By Messrs James Watt and Co.
47. Link-Motion. By J. F. Spencer.

LOCOMOTIVE LINK-MOTION.

55. The Solid Link-Motion of the Locomotive "King-Coil," Ardrossan Railway. Constructed by William Robertson, 1851.
56. Arrangement and Motion Diagrams of Allan's Straight Link-Motion as applied to Locomotive Engines.
57. Allan's Straight Link-Motion, ditto.
No.
58. Arrangement of Link-Motion, for a Locomotive. Constructed by Sharp, Stewart, and Co., Limited, 1867.
59. Arrangement of Link-Motion, &c., of a Goods Locomotive. Constructed by Messrs. Dubs and Co., of Glasgow, January, 1868, for the G.I.P.R.
60. Arrangement of Link-Motion, &c., of a Passenger Locomotive. Constructed by Messrs. Dubs and Co., of Glasgow, January, 1868, for the G.I.P.R. G. Berkley, Esq., Engineer.
61. Details of Link-Motion and Reversing Gear for Tank Locomotive Engine. Constructed by Messrs. Kitson and Co., Leeds, for the G.I.P.R. G. Berkley, Esq., Engineer.
61A. Reversing Gear for Goods Engine for the G.I.P.R. G. Berkley, Esq., Engineer.
62. Allan's Link-Motion as applied by J. H. Beattie, Esq. L. & S.W.R., 1870.
63. Illustrations of Curved and Straight Links, as used from the year 1842 to 1870.
64. Valve Diagram and Arrangement of Link-Motion for Goods Engine, for the G.I.P.R. G. Berkley, Engineer.
64A. Valve Diagram and Arrangement of Link-Motion for Locomotive Engine for the G.I.P.R. G. Berkley, Esq., Engineer.

GEOMETRY OF LINK-MOTION AND SLIDE VALVES' ACTION.

64. Valve Diagram and Arrangement of Link-Motion for Goods Engine, for the G.I.P.R. G. Berkley, Engineer.
64A. Valve Diagram and Arrangement of Link-Motion for Locomotive Engine for the G.I.P.R. G. Berkley, Esq., Engineer.
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D. Geometry of the Link-Motion by N. P. Burgh . 209
E. ,, ,, ,, 209
F. Geometry of the Vibration of the Link, by N. P. Burgh 211
G. Geometrical Delineation of the Action of the Slide Valve and Link-Motion, by N. P. Burgh 212
H. Geometrical Delineation of the Action of the Slide Valve and Link Motion, by Messrs. James Watt and Co. 213

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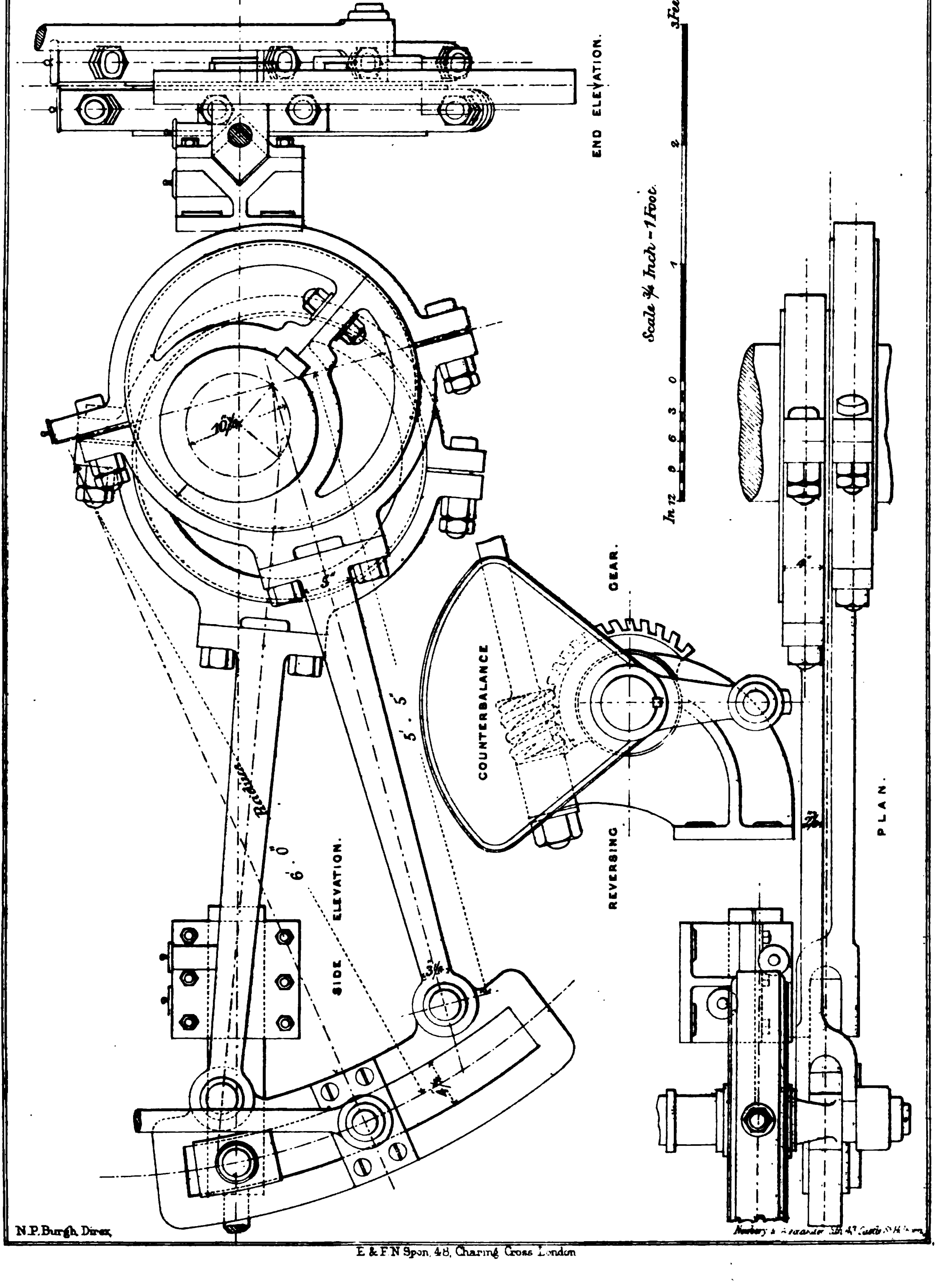
LINK MOTION AND PORTION OF REVERSING GEAR OF THE ENGINES FITTED IN H.M.S. "ARETHUSA" 500 HP. NOML. COLLY BY MESSRS. JOHN PENN & SON.

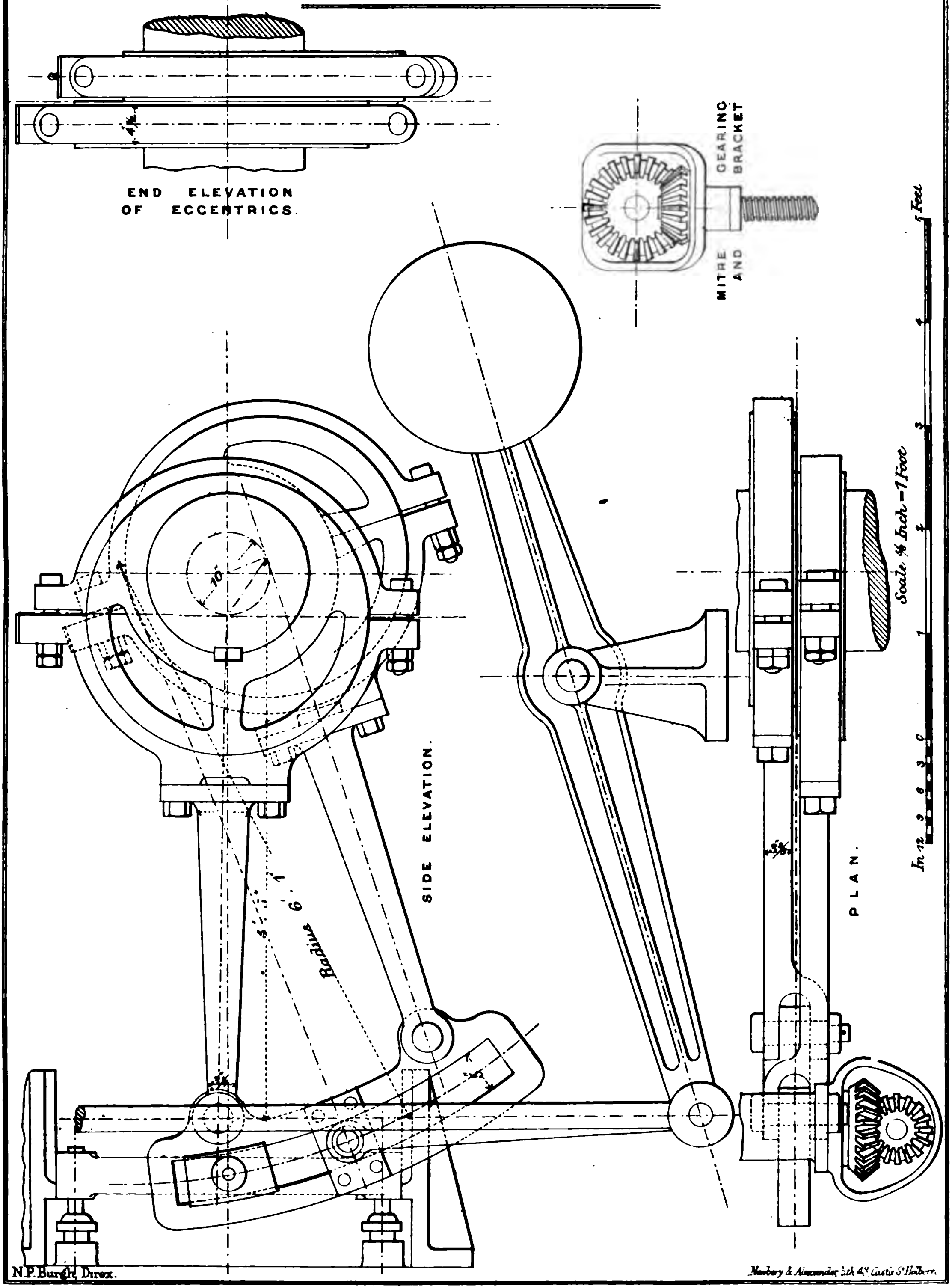


N.P. Burgh, Direx.

Newbery & Alexander Sth 43 Castle St Holborn

E & F N Spon, 48, Charing Cross London

LINK MOTION AND REVERSING GEAR, OF THE ENGINES FITTED IN H.M.S. "NORTHUMBERLAND" 1350 HP. Nº COLL'Y BY MESSRS JOHN PENN & SON.


END ELEVATION OF ECCENTRICS.
4⅛
MITRE AND GEARING BRACKET
10"
Radius 6' 1"
5⅜
SIDE ELEVATION.
5¾
PLAN.
Scale ¾ Inch – 1 Foot
In 12 9 6 3 0 1 2 3 4 5 Feet

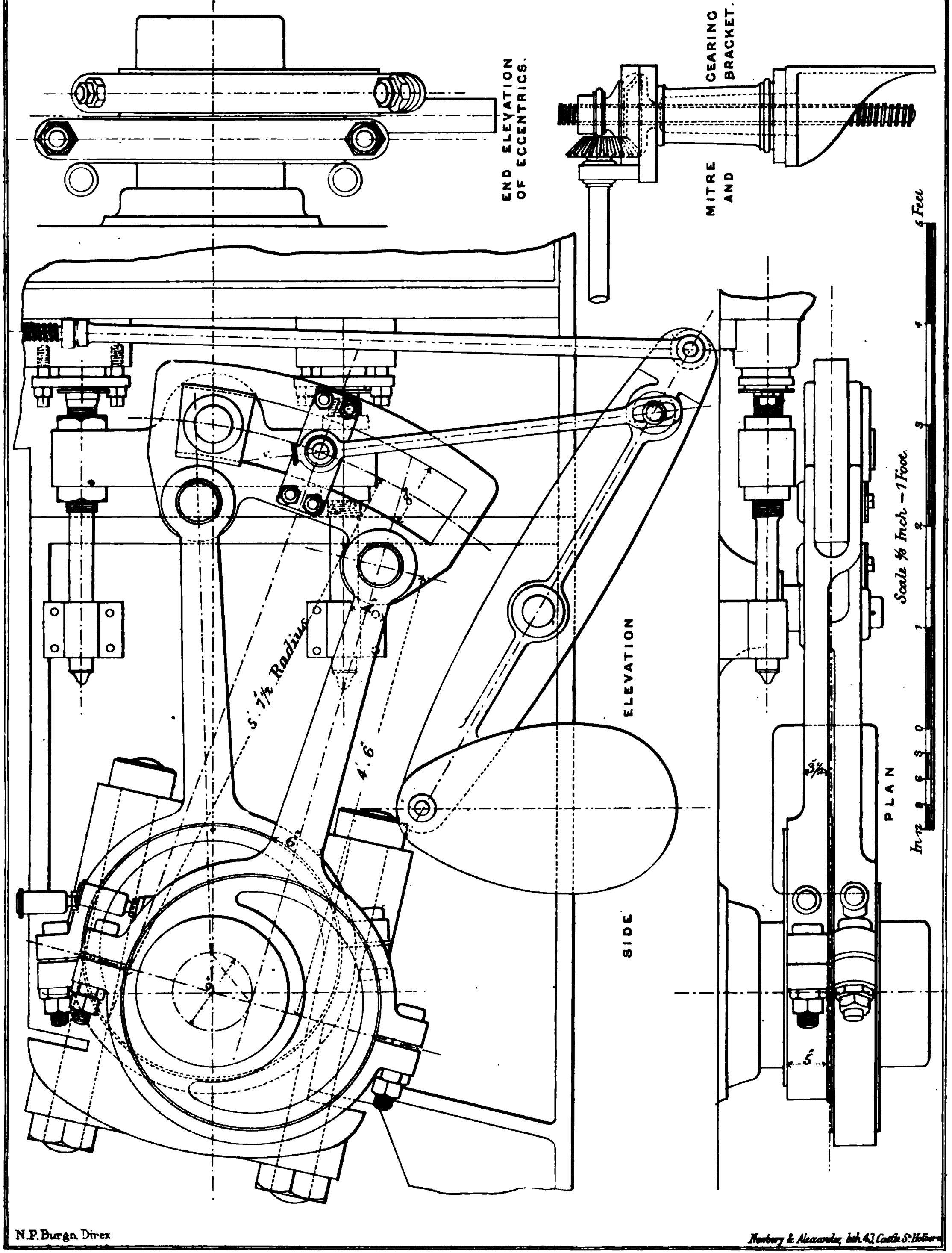
N.P. Burgh, Direx.

Newbery & Alexander, Lith 4, Castle St Holborn.

E & F N Spon, 43, Charing Cross, London

Plate 3

LINK MOTION AND PORTION OF REVERSING GEAR OF THE ENGINES FITTED IN THE S.S. "ROMA" & "VENETIA" 900 H.P. NOML COLLY BY MESSRS MAUDSLAY SONS & FIELD.


END ELEVATION OF ECCENTRICS.
MITRE AND GEARING BRACKET.
ELEVATION
SIDE
PLAN
5' 7½" Radius
4' 6"
8"
6"
3½"
5"
Scale ⅜ Inch – 1 Foot
In 12 9 6 3 0 1 2 3 4 5 Feet

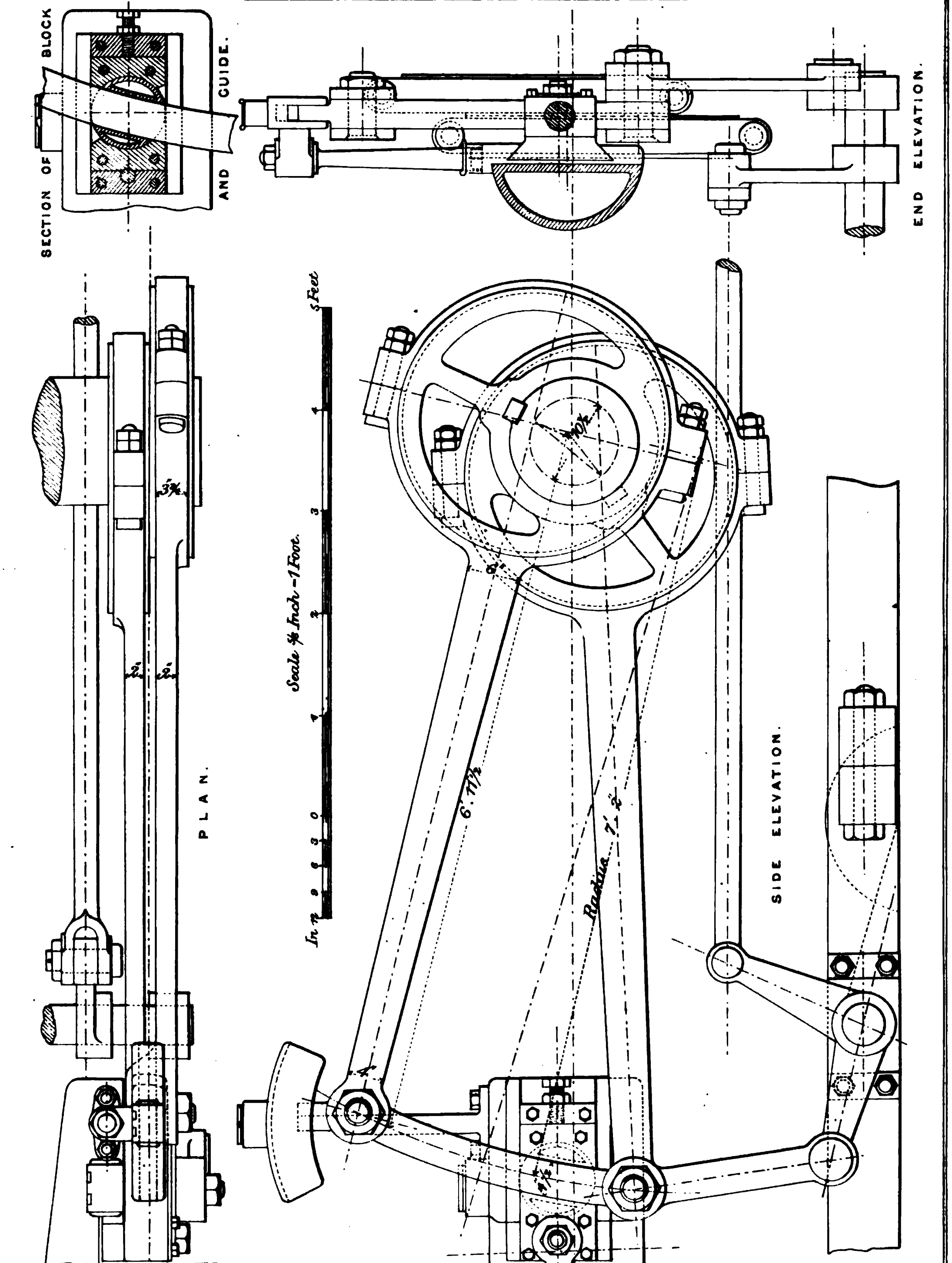
N.P. Burgh Direx

Newbury & Alexander, lith. 43 Castle St. Holborn

E & F N Spon, 48, Charing Cross, London.

Plate 4.

LINK MOTION AND PORTION OF REVERSING GEAR, FITTED TO ENGINES 400 HP. NOML. COLLY
BY MESSRS. HUMPHRYS & TENNANT.

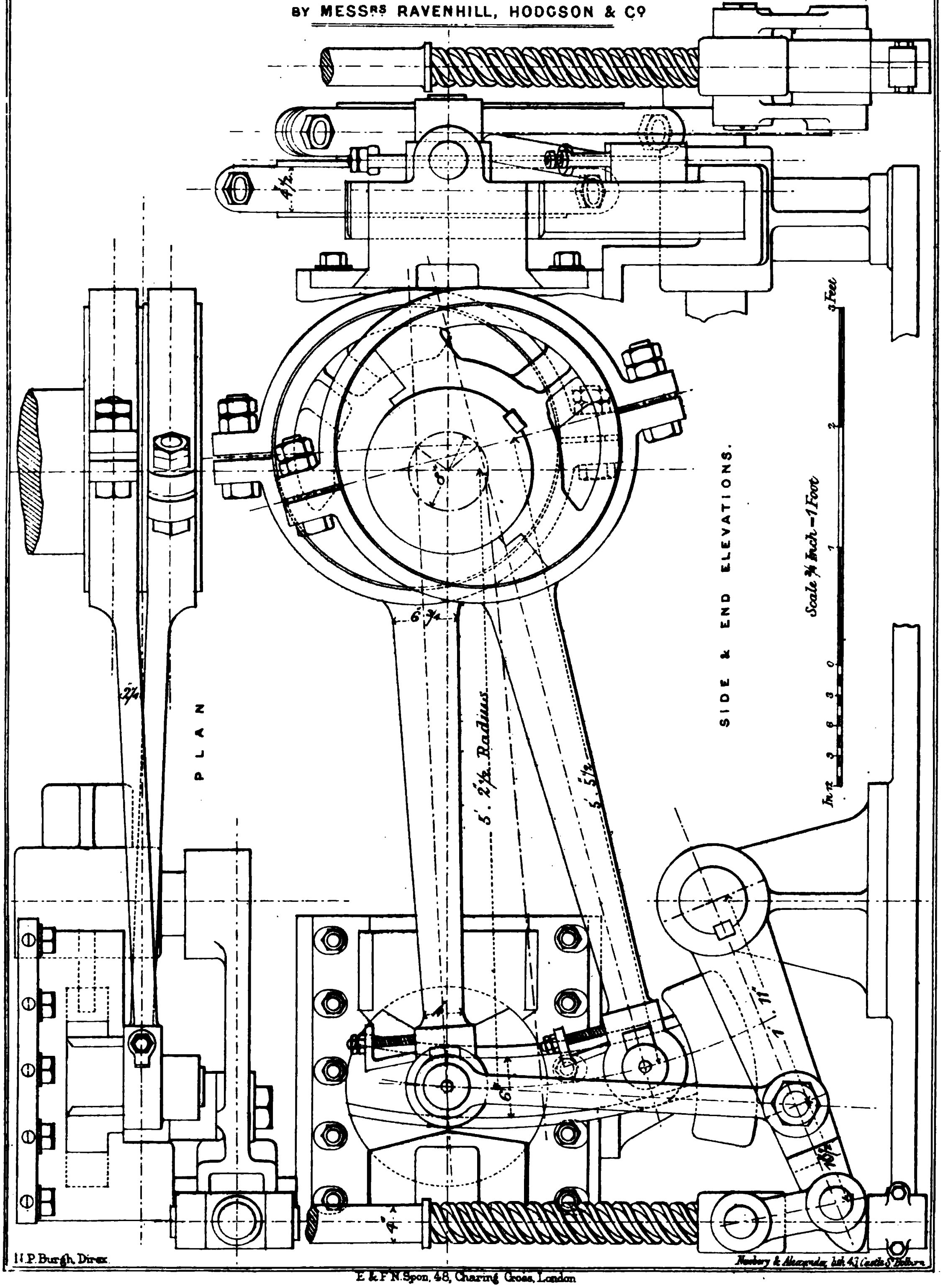


N. P. Burgh. Direx.

Newbery & Alexander, lith. 43, Castle St. Holborn

E & F N Spon 48, Charing Cross, London

LINK MOTION AND PORTION OF REVERSING GEAR OF THE ENGINES FITTED IN THE TURKISH FRIGATE "SULTAN MAHMOUD" 900 H.P. NOML. COLLY. BY MESSRS RAVENHILL, HODGSON & CO.



H. P. Burgh Direx.

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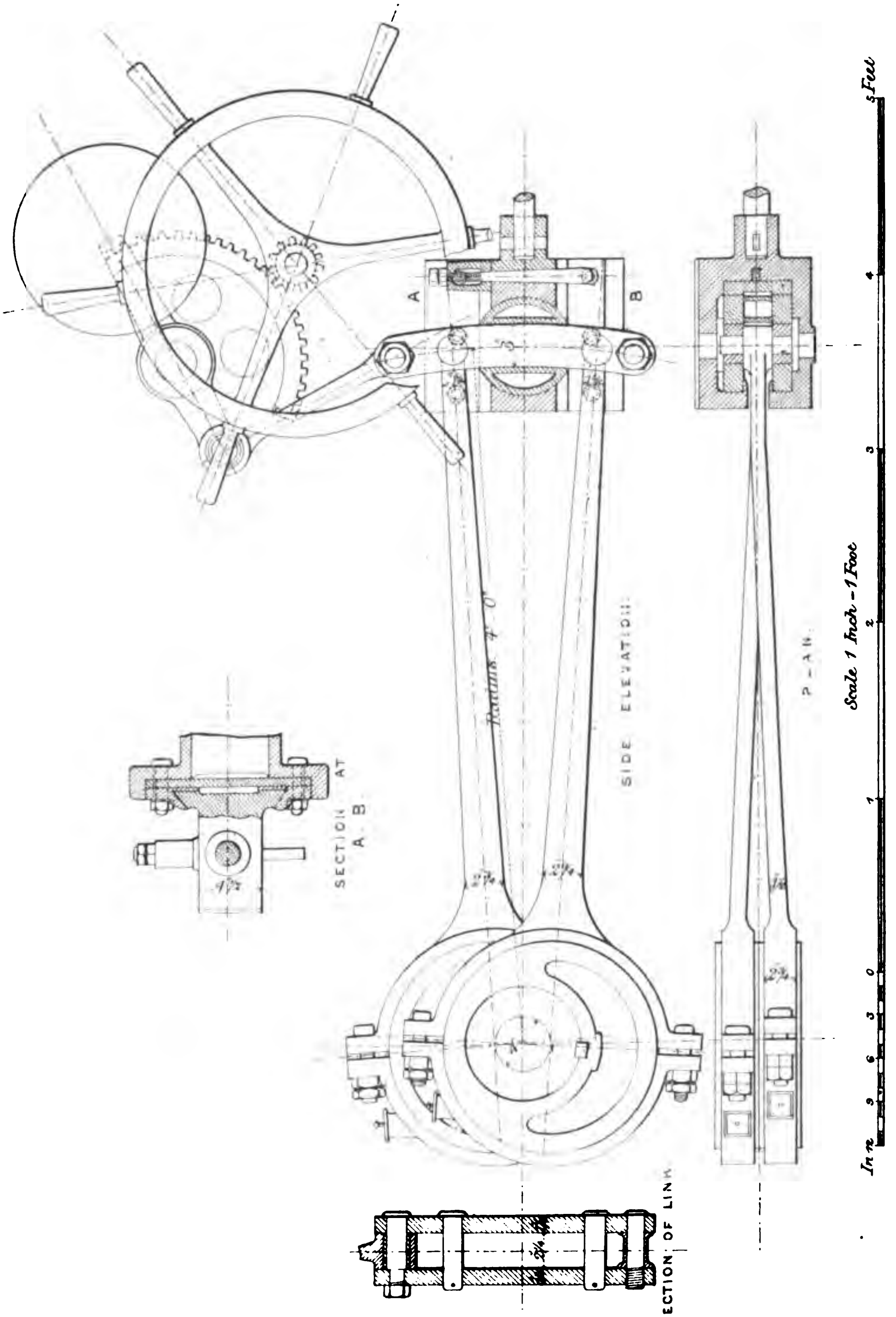
E. & F. N. Spon, 48, Charing Cross, London

LINK MOTION AND REVERSING GEAR OF THE ENGINES FITTED IN H.M.S. "ENTERPRISE" 160, H.P. NOML. COLLY
BY MESSRS RAVENHILL, HODGSON & Co

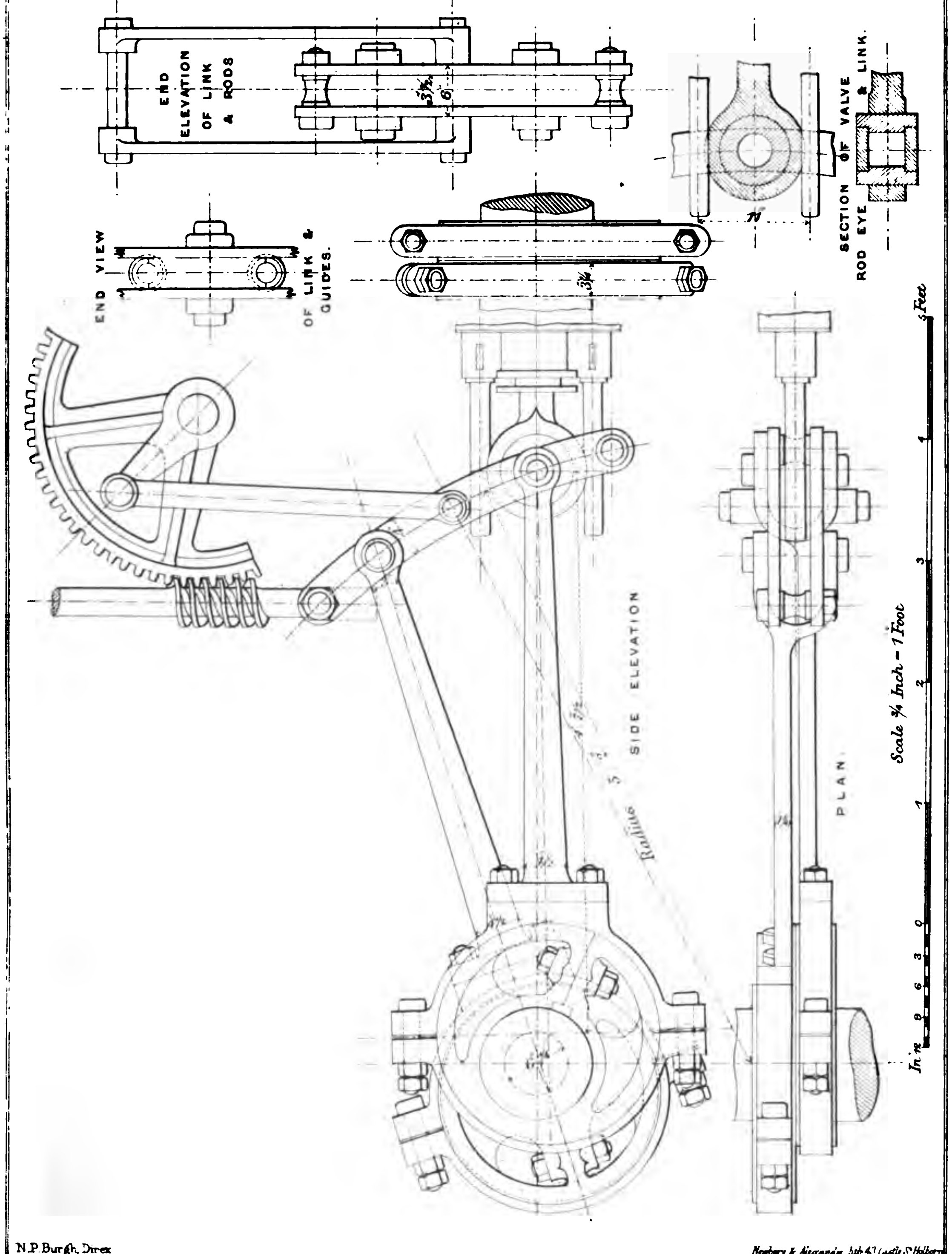


N. P. Burgh, Direx

Newbery & Alexander lith [illegible]

E. & F. N. Spon, 48 Charing Cross, London

LINK MOTION AND REVERSING GEAR
FITTED IN THE ROYAL-MAIL. S.S. "RUAHINE" TWIN SCREW ENGINES, 350 HP. NOML. COLLY
BY MESSRS J & W. DUDGEON.


END ELEVATION OF LINK & RODS
3¾
6
SECTION OF VALVE ROD EYE & LINK.
END VIEW OF LINK & GUIDES.
3¾
SIDE ELEVATION
PLAN.
Radius 5' 4"
Scale ¾ Inch - 1 Foot
In. 12 9 6 3 0 1 2 3 4 5 Feet

N.P. Burgh, Direx

Newbury & Alexander, lith 47 Castle St Holborn

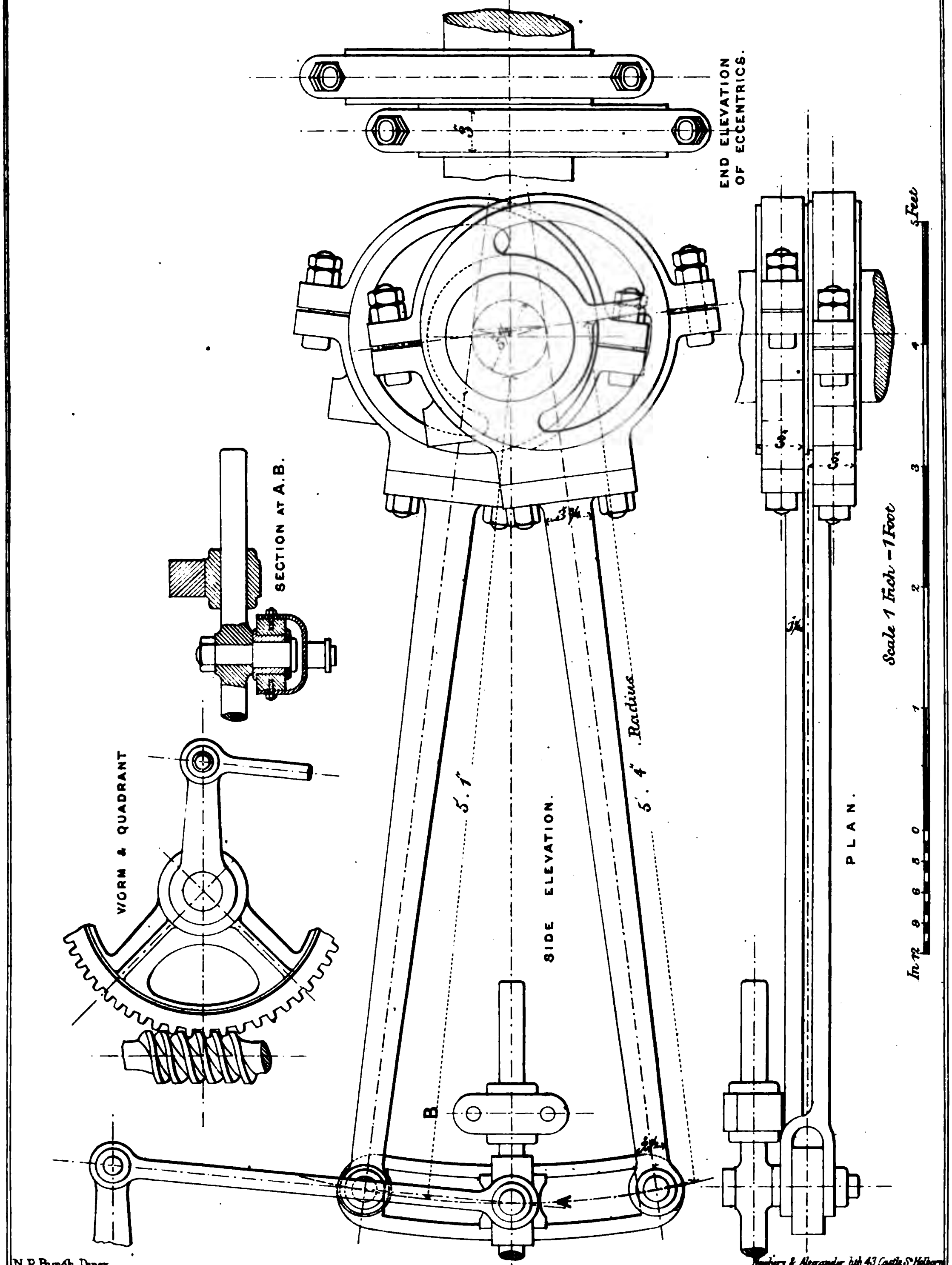
E & F.N Spon, 48, Charing Cross, London

Plate 8.

LINK MOTION AND REVERSING GEAR.

FITTED IN THE S.S. "MARY AUGUSTA" TWIN SCREW ENGINES 300 HP. NOML. COLLY

BY MESSRS J & W. DUDGEON.



N P. Burgh. Direx

Newbery & Alexander, lith. 43, Castle St Holborn

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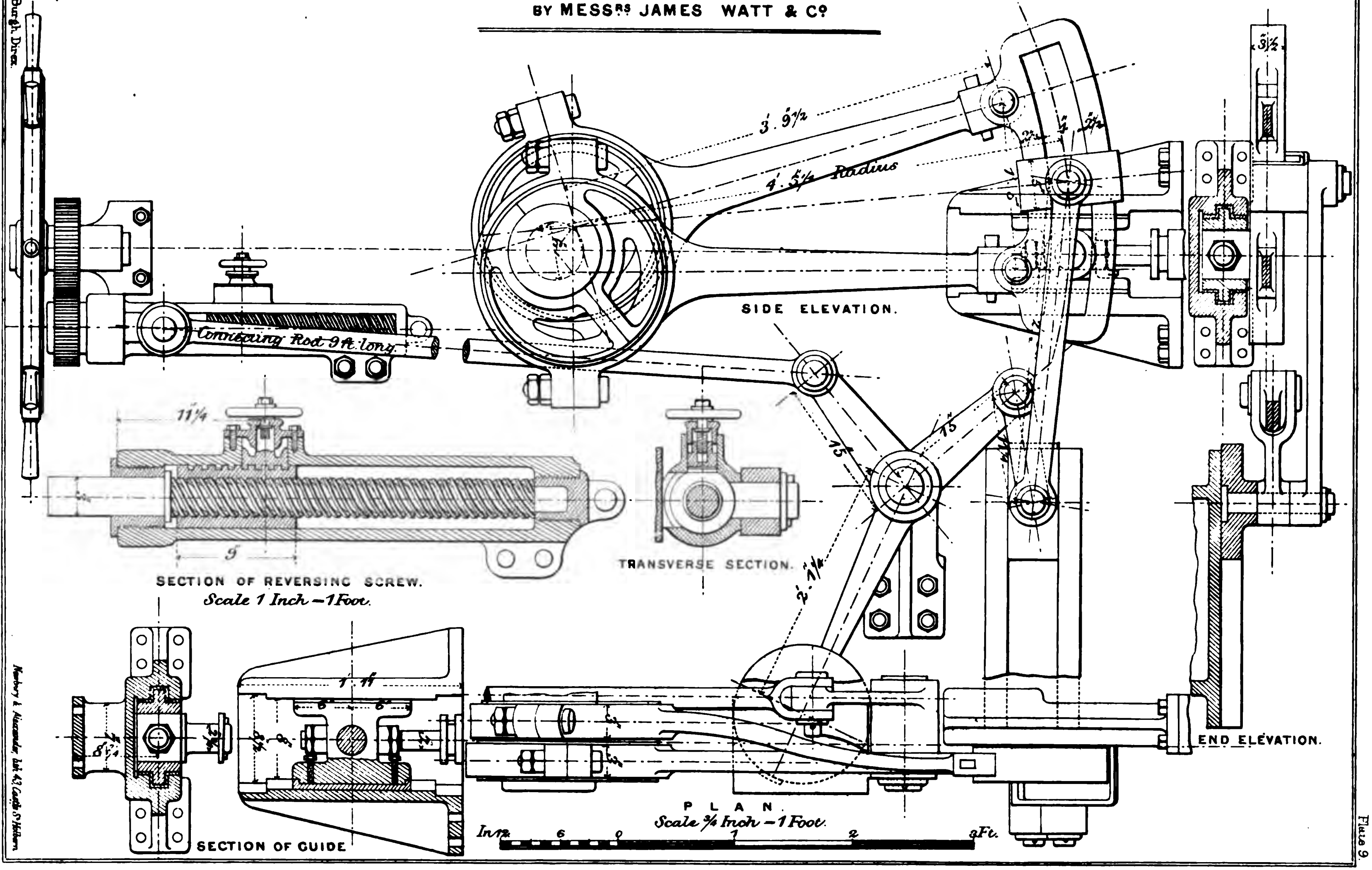
Plate 9.

LINK MOTION AND PORTION OF THE REVERSING GEAR OF THE ENGINES, FITTED IN H.M.S. "RESEARCH" 200 HP. NOML. COLLY BY MESSRS JAMES WATT & Co.



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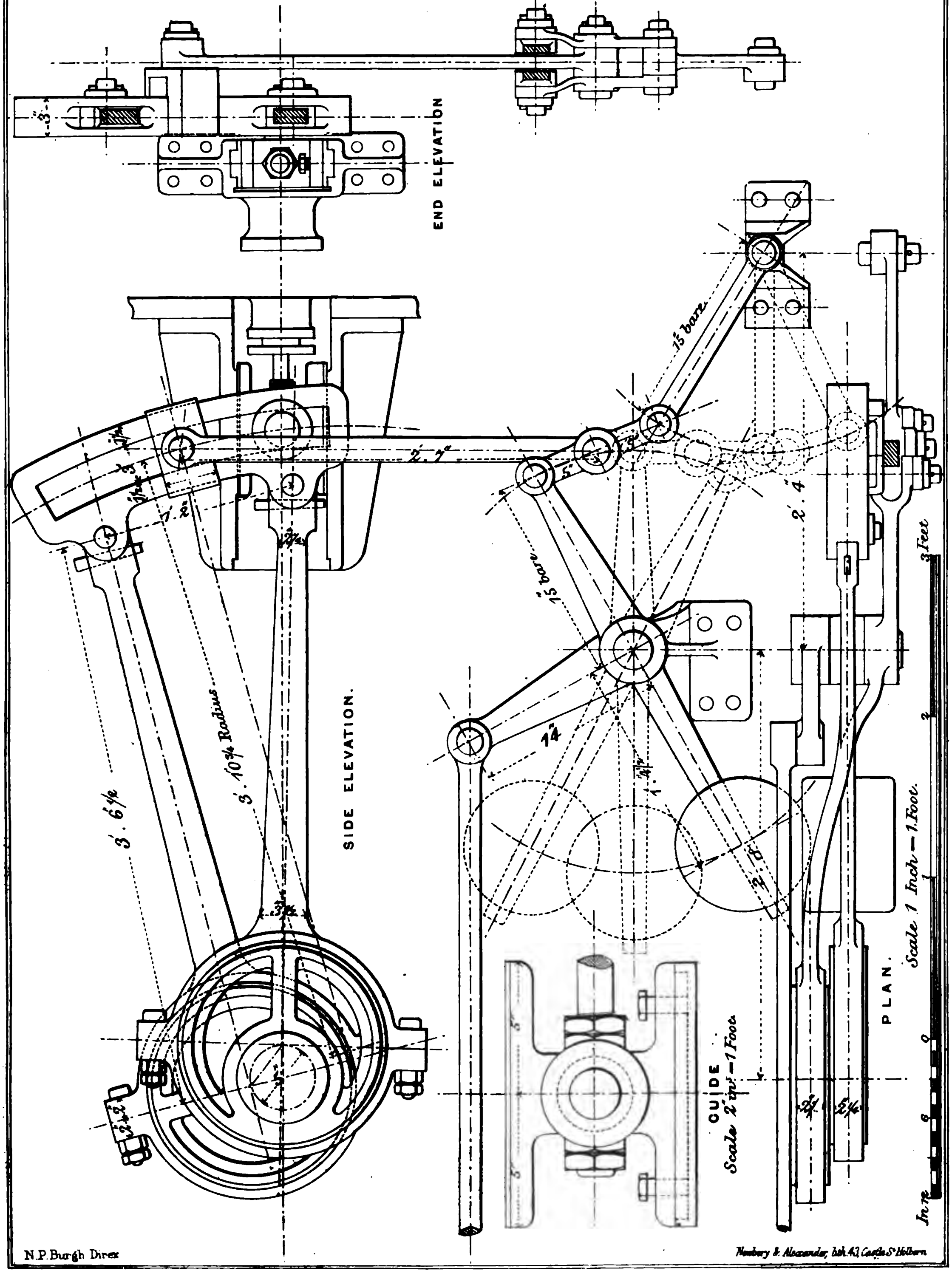
LINK MOTION AND PORTION OF REVERSING GEAR, FITTED IN S. S. "MÆDUSA" AND "TRITON". TWIN SCREW ENGINES, 200 HP. NOML. COLLY. BY MESSRS. JAMES WATT & Co.



N.P. Burgh Direx

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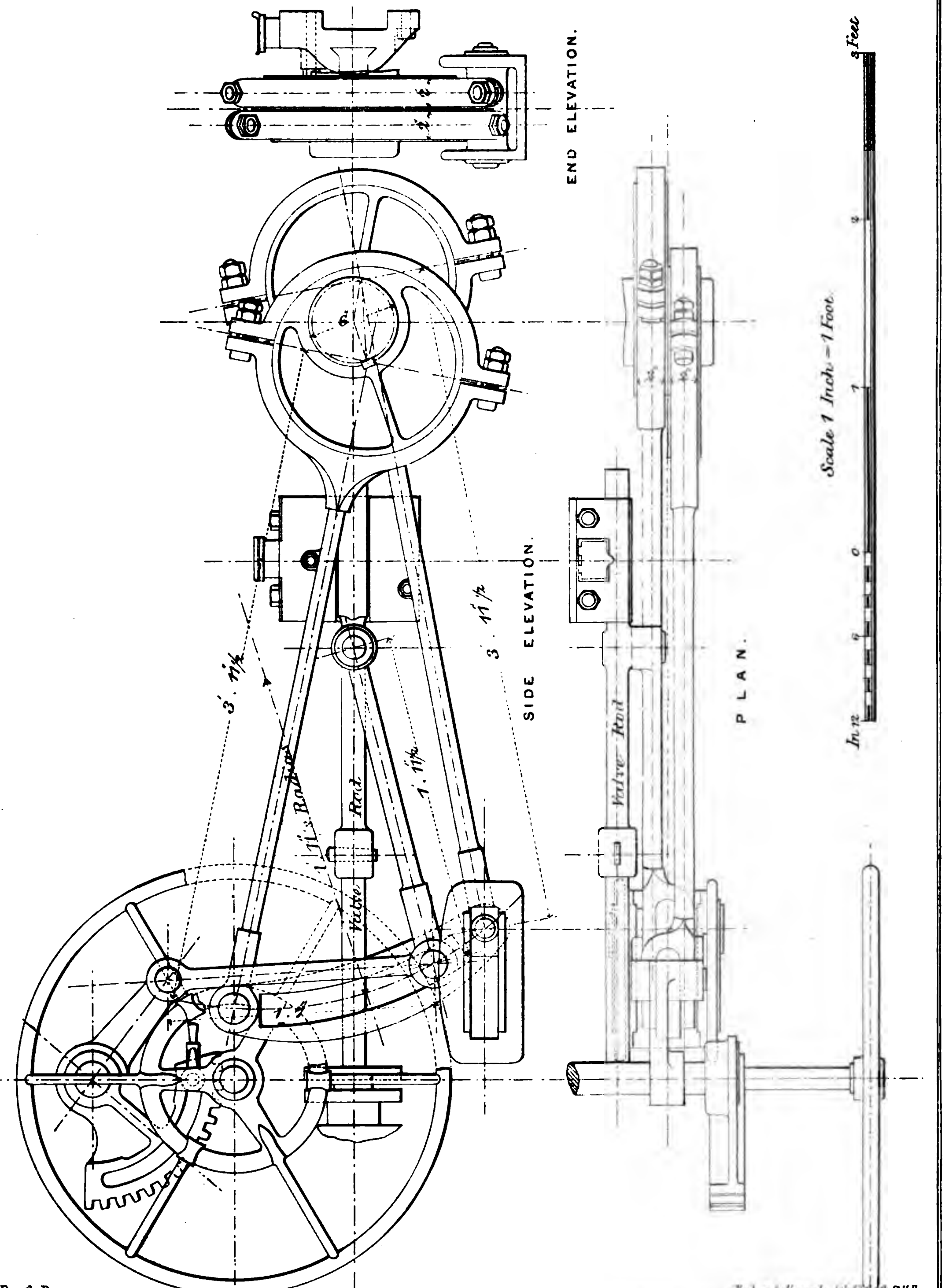
E. & F. N. Spon, 48, Charing Cross, London.

LINK MOTION AND REVERSING GEAR OF THE ENGINES, 70 HP. NOML COLLY
BY R. NAPIER & SON.

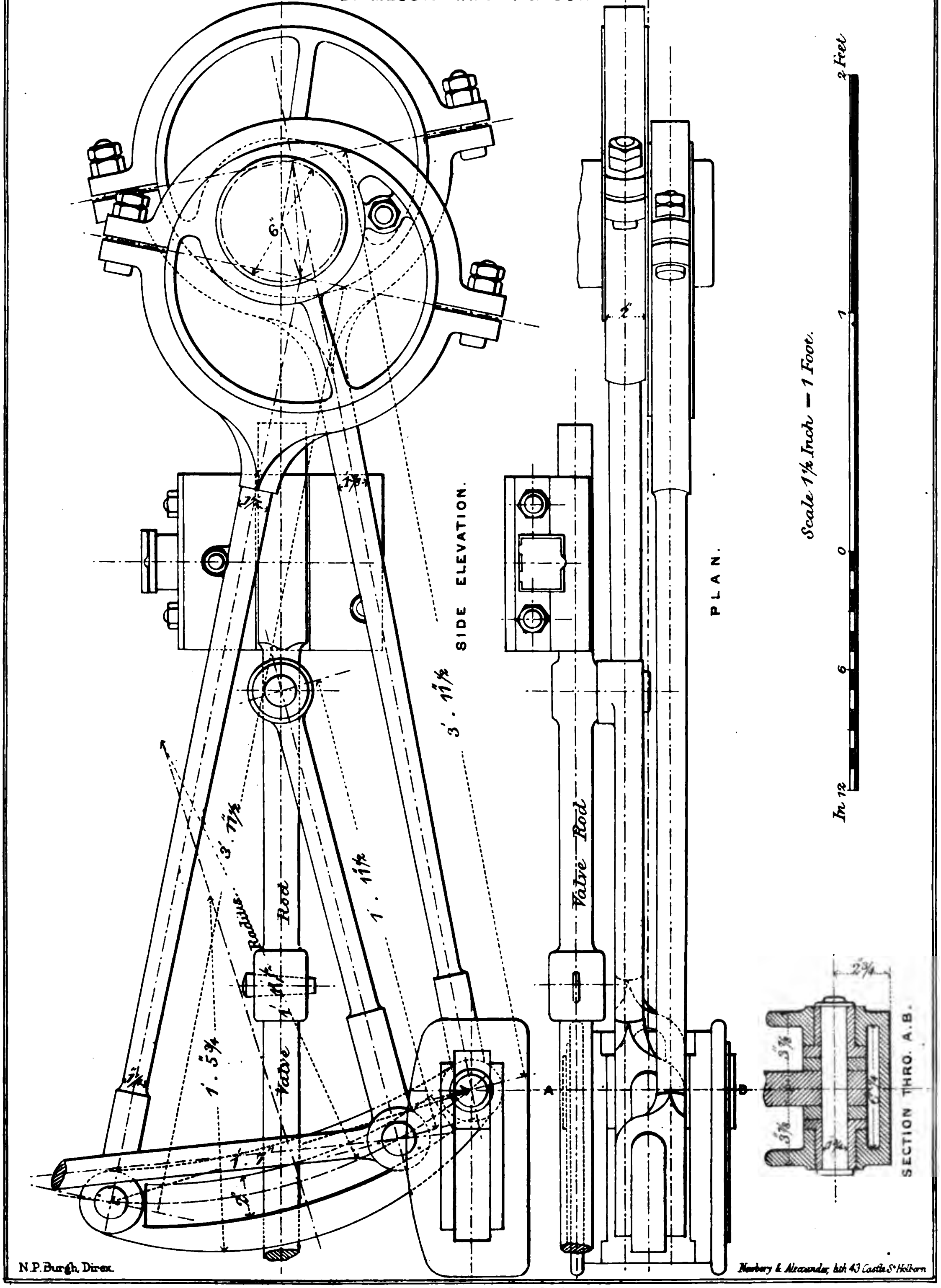


N.P. Burgh, Direx.

Newbery & Alexander, lith. 47 Castle St Holborn

E & F N Spon 48, Charing Cross, London

LINK MOTION OF THE ENGINES 70 HP. NOM^L. COLLY
BY MESS^RS NAPIER & SON.



N.P. Burgh, Direx.

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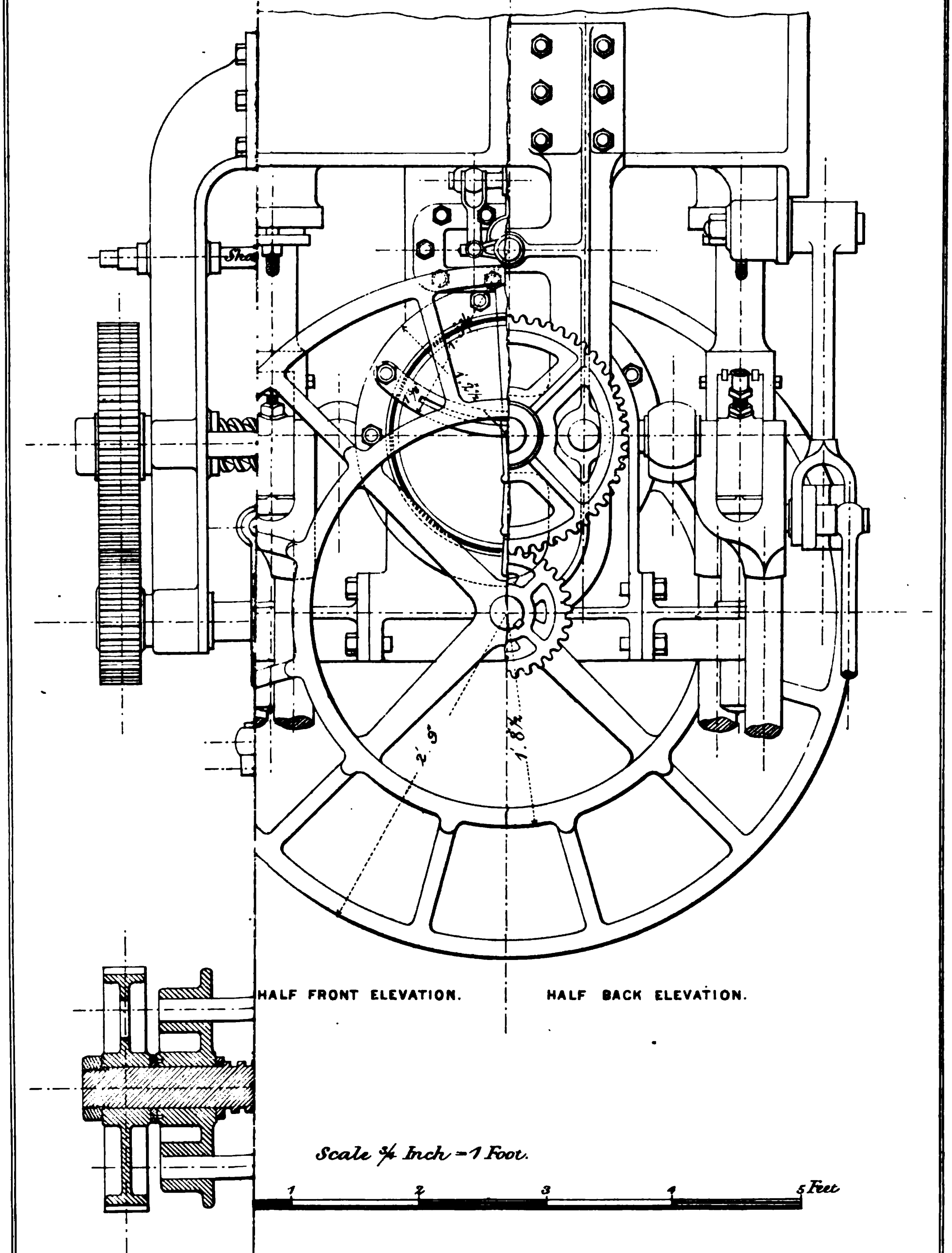
STE D"VILLE DE PARIS" 800 H.P. NOML. COLLY.



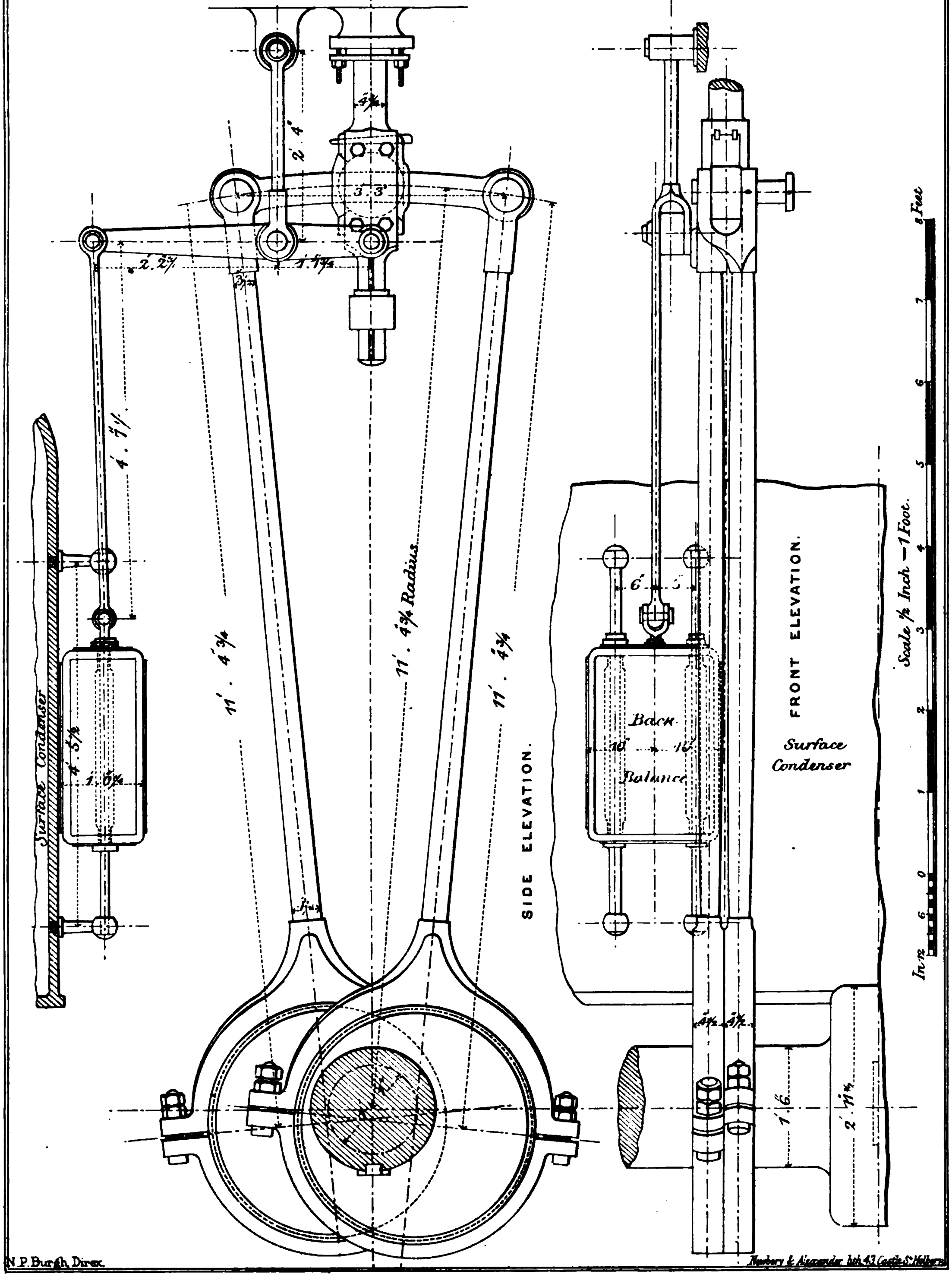
HALF FRONT ELEVATION. HALF BACK ELEVATION.

Scale ¾ Inch = 1 Foot.

N. P. Burgh. Direx.

Newbery & Alexander, lith. 43, Castle St. Holborn

LINK MOTION AND BACK BALANCE, OF THE ENGINES, FITTED IN S.S. "PERIERE" AND "VILLE DE PARIS" 800 HP. NOM! COLLY BY MESSRS NAPIER & SON.



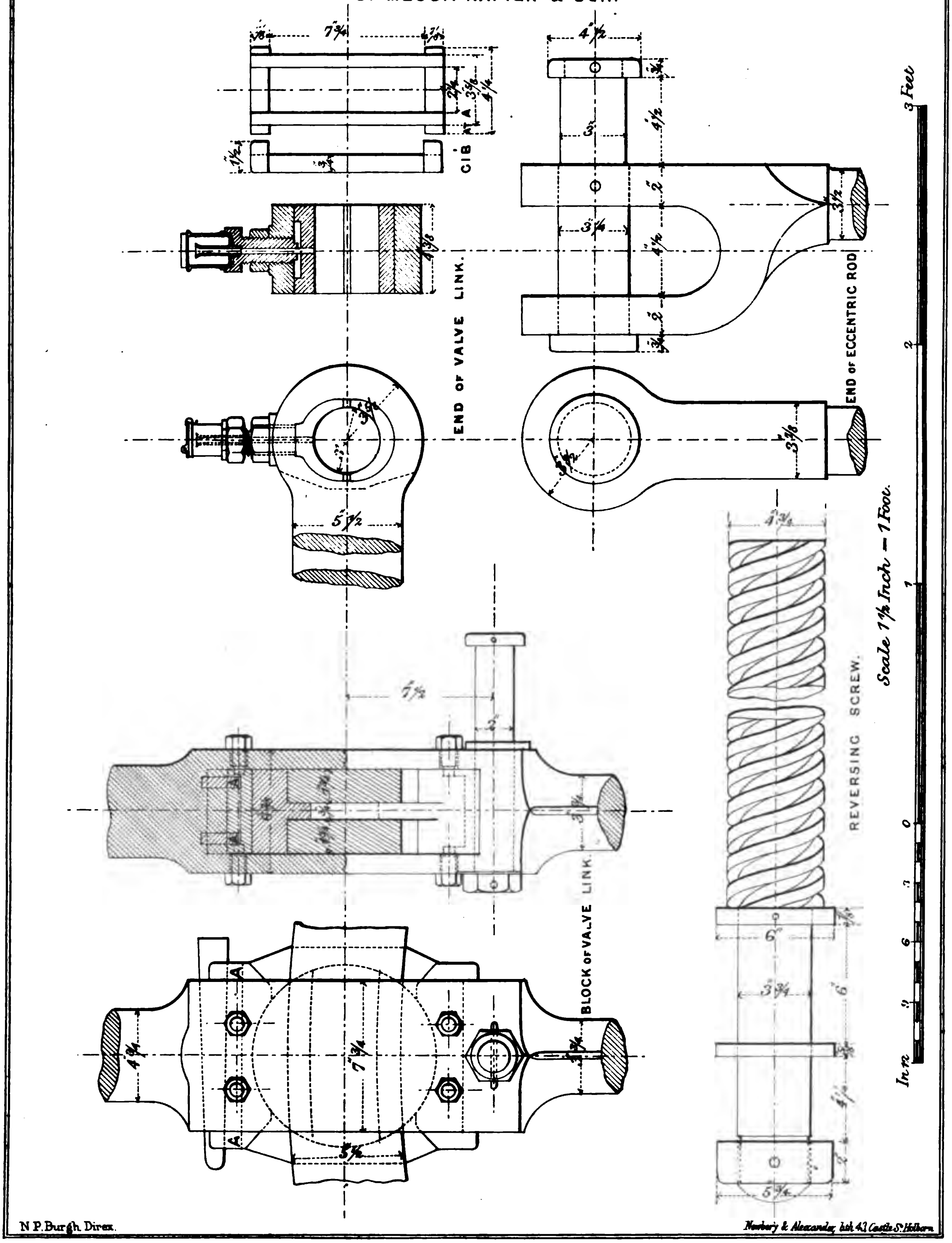
N. P. Burgh, Direx.

Newbery & Alexander lith 43 Castle St Holborn

E & F. N. Spon, 48, Charing Cross, London.

Plate 15

MAIN DETAILS OF THE LINK MOTION OF THE ENGINES FITTED IN S.S. "PERIERE" AND "VILLE DE PARIS" 800 HP. NOML. COLLY BY MESSRS. NAPIER & SON.

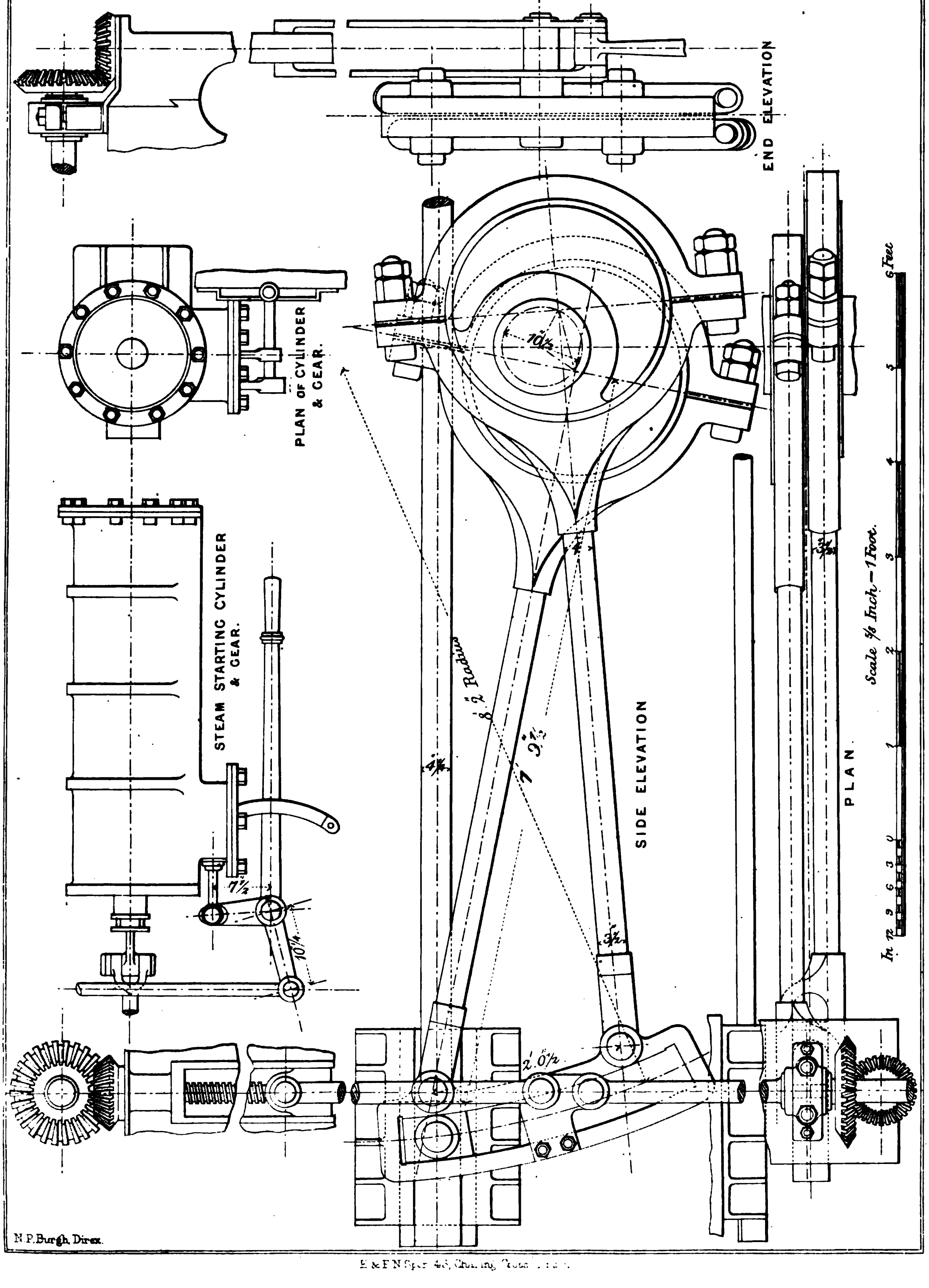


N.P. Burgh. Direx.

Newbury & Alexander, lith 43 Castle St. Holborn

E. & F.N. Spon 48, Charing Cross, London.

LINK MOTION & PORTION OF THE STEAM & HAND REVERSING-GEAR OF THE ENGINES. FITTED IN H.M.S. "HECTOR", 800 HP., NOML., COLLY., BY MESSRS. R. NAPIER & SON.



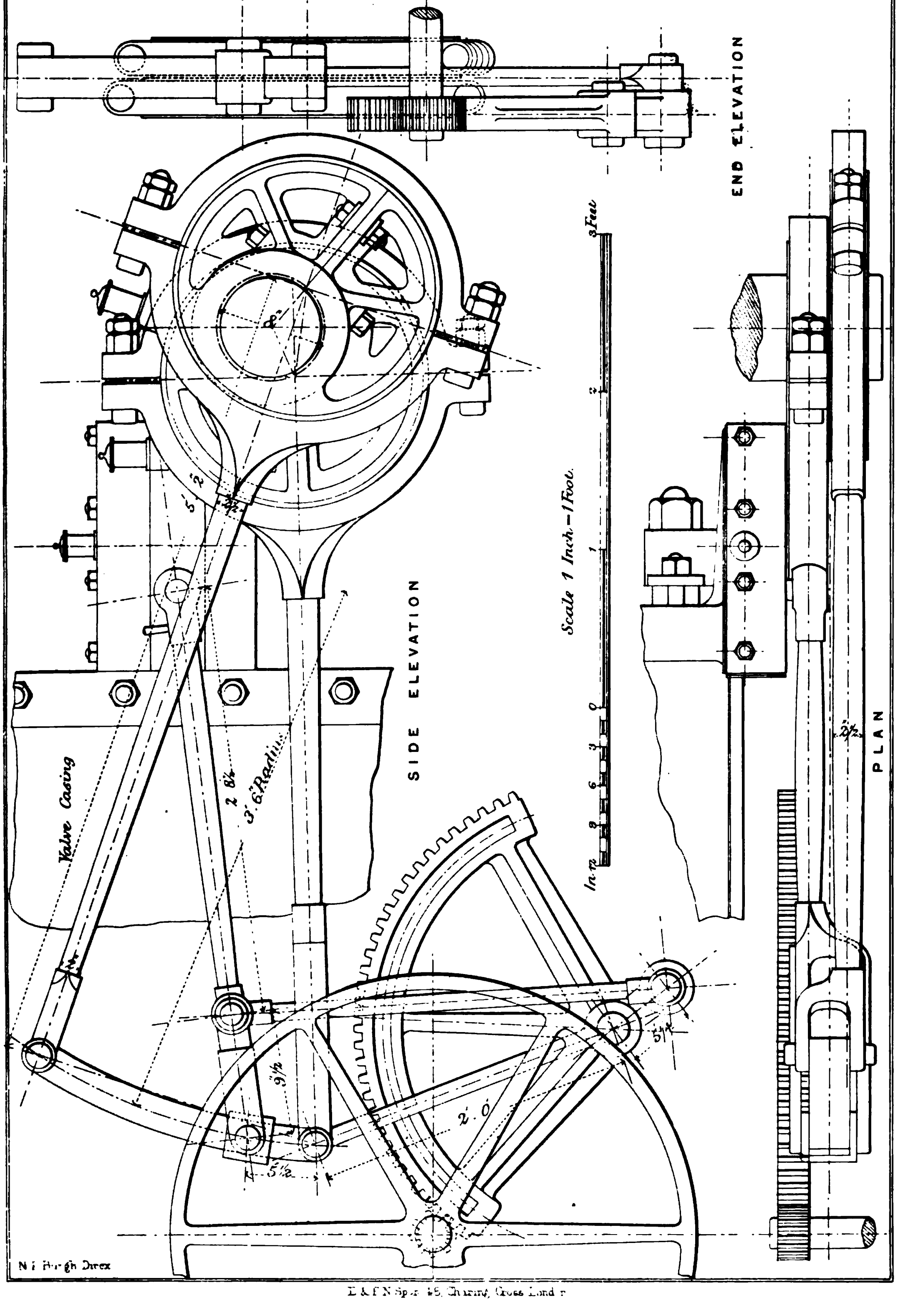
N. P. Burgh, Direx.

E & F N Spon 48, Charing Cross London.

Plate 17.

LINK MOTION & REVERSING-GEAR OF THE ENGINES.

FITTED IN THE DANISH, ARMOUR-CASED, CUPOLA, IRON SHIP "ROLF KRAKE," 235 HP. NOML. COLLY,
BY MESSRS. R. NAPIER & SON.

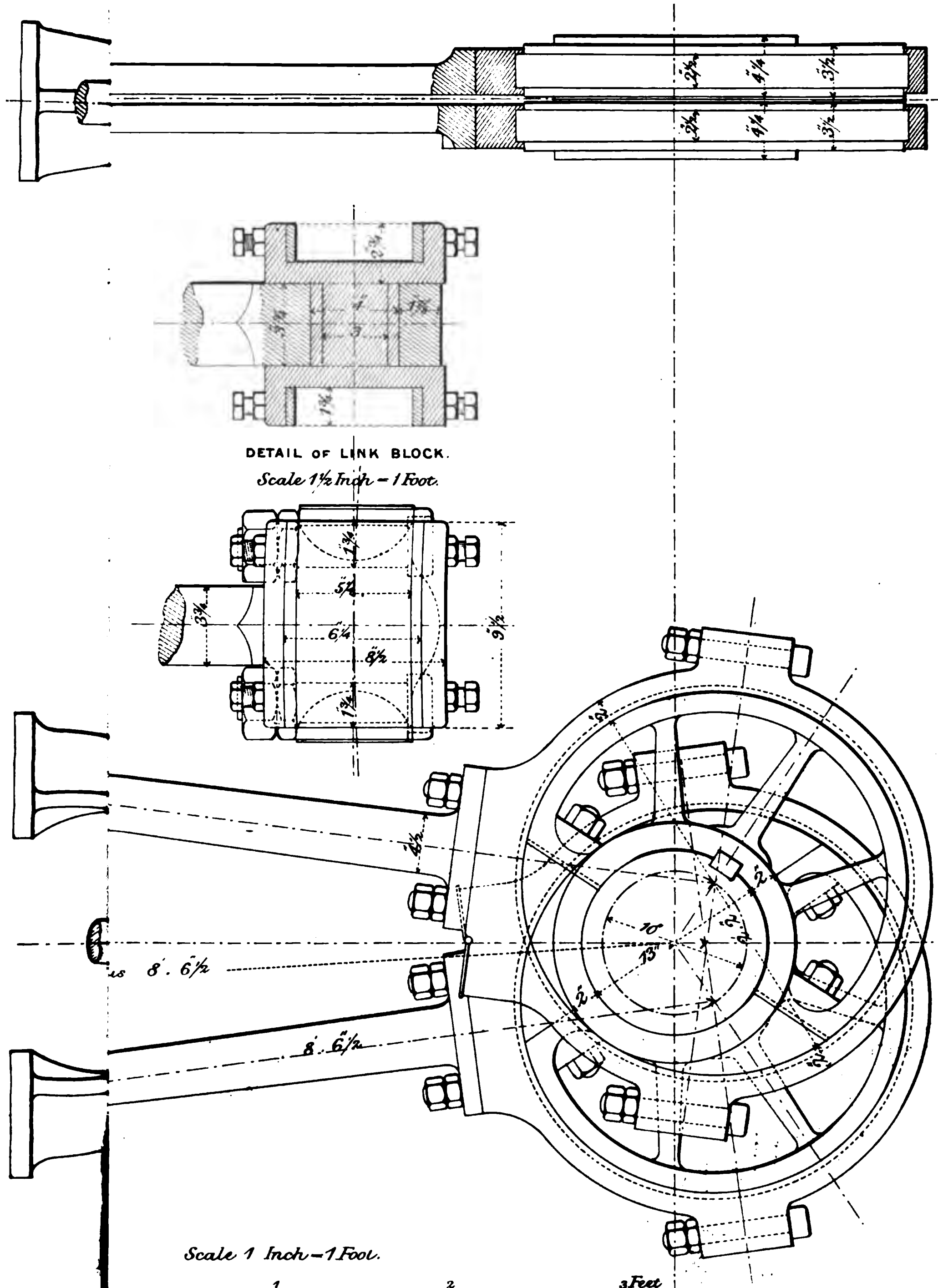


N. P. Burgh Direx

E & F. N. Spon 48, Charing Cross London

ENGINES, 250 HP. NOML COLLY

D.



DETAIL OF LINK BLOCK.

Scale 1½ Inch = 1 Foot.

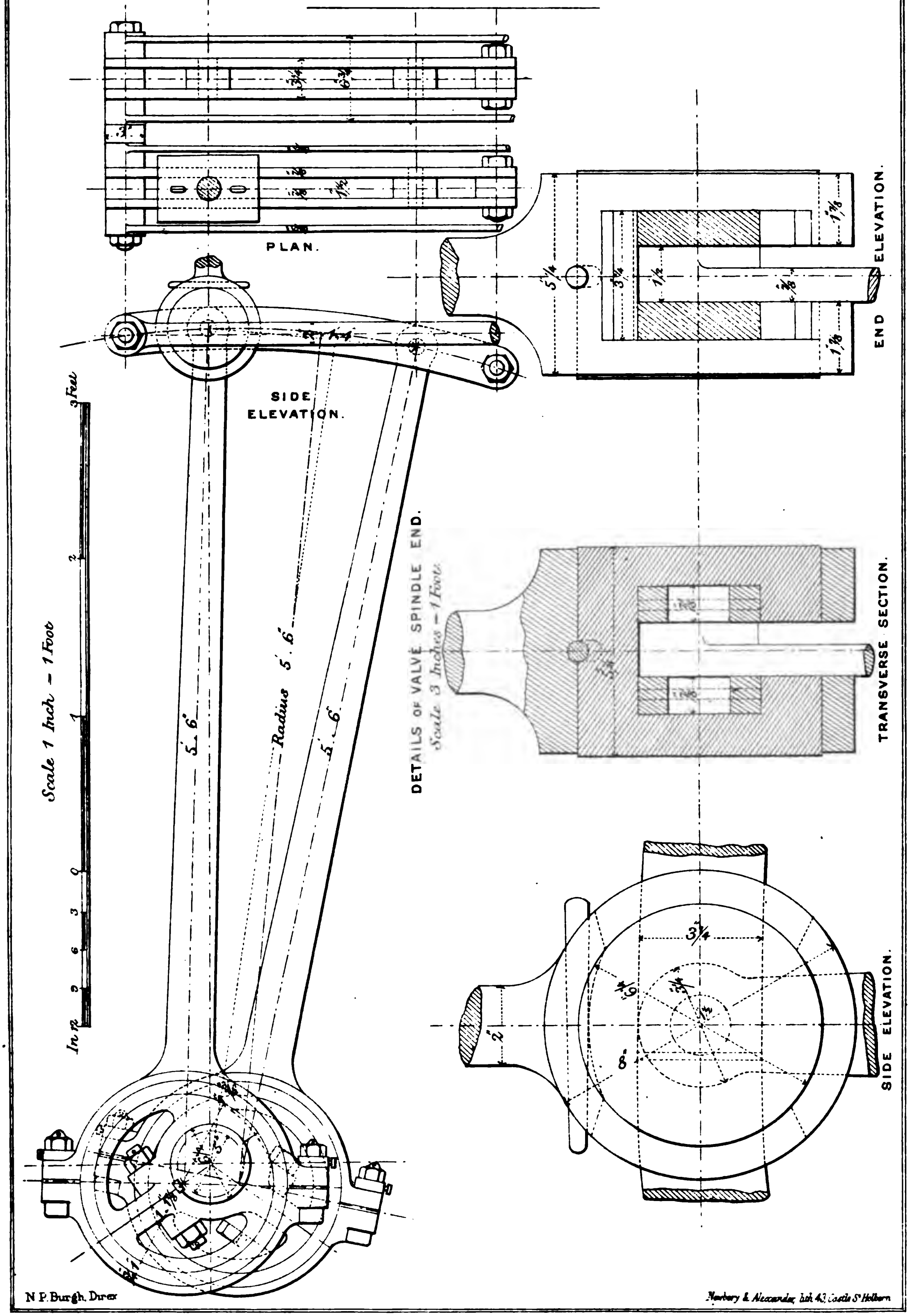
Scale 1 Inch – 1 Foot.

1 2 3 Feet

N P Burgh Direx

Newbury & Alexander, lith 43 Castle St Holborn

LINK MOTION OF THE ENGINES. FITTED IN S.S. "DUBLIN." 70 HP. COLLY BY MESSRS COURTNEY, STEPHENS & Co DUBLIN.

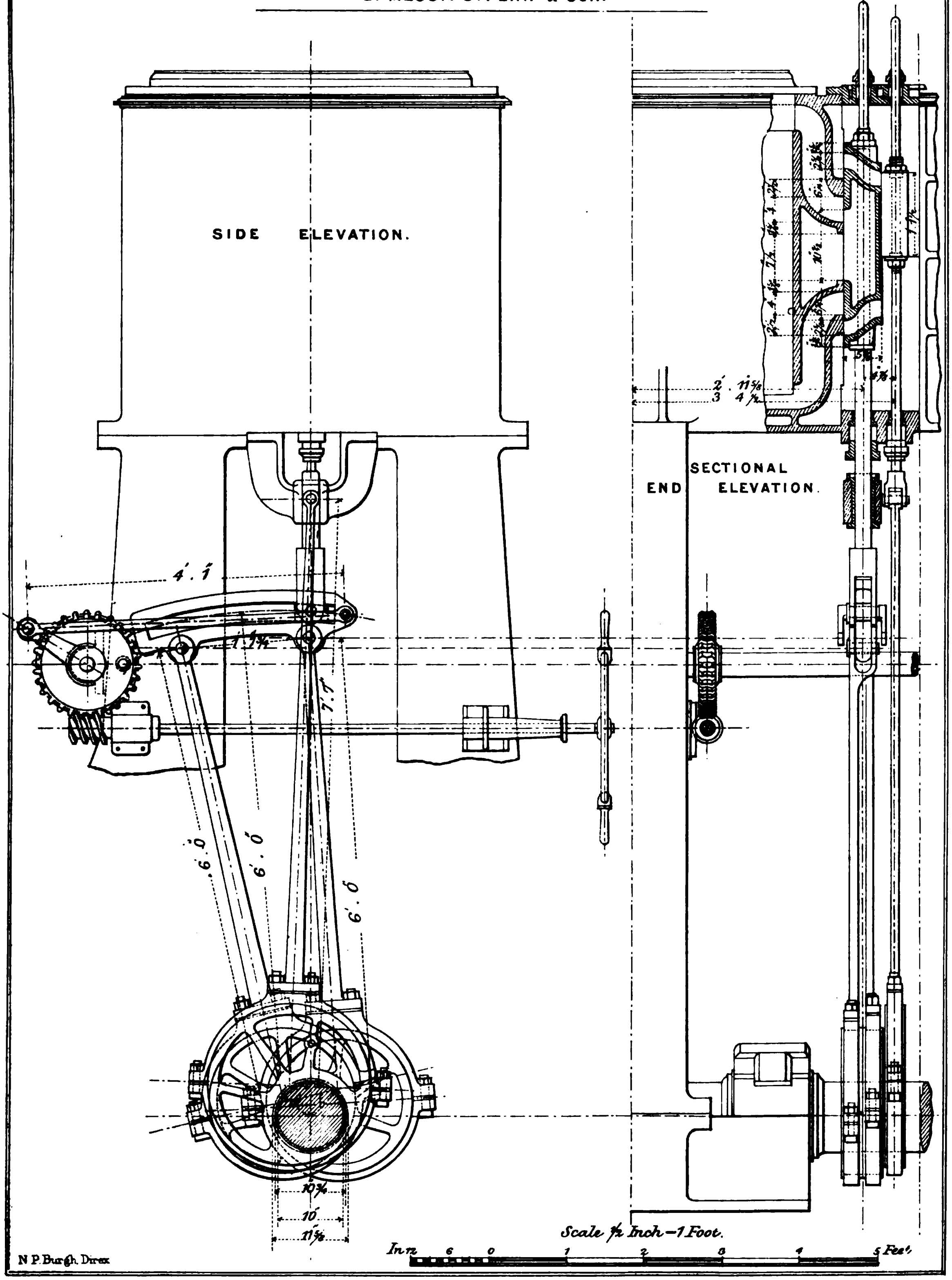


N P Burgh, Direx

Newbery & Alexander, lith 43 Castle St Holborn

E & F N Spon, 48, Charing Cross, London

ARRANGEMENT OF LINK MOTION & EXPANSION GEAR FOR ENGINES OF 160 HP. AS FITTED FOR THE R.S.N.Cº BY MESSRS J. PENN & SON.



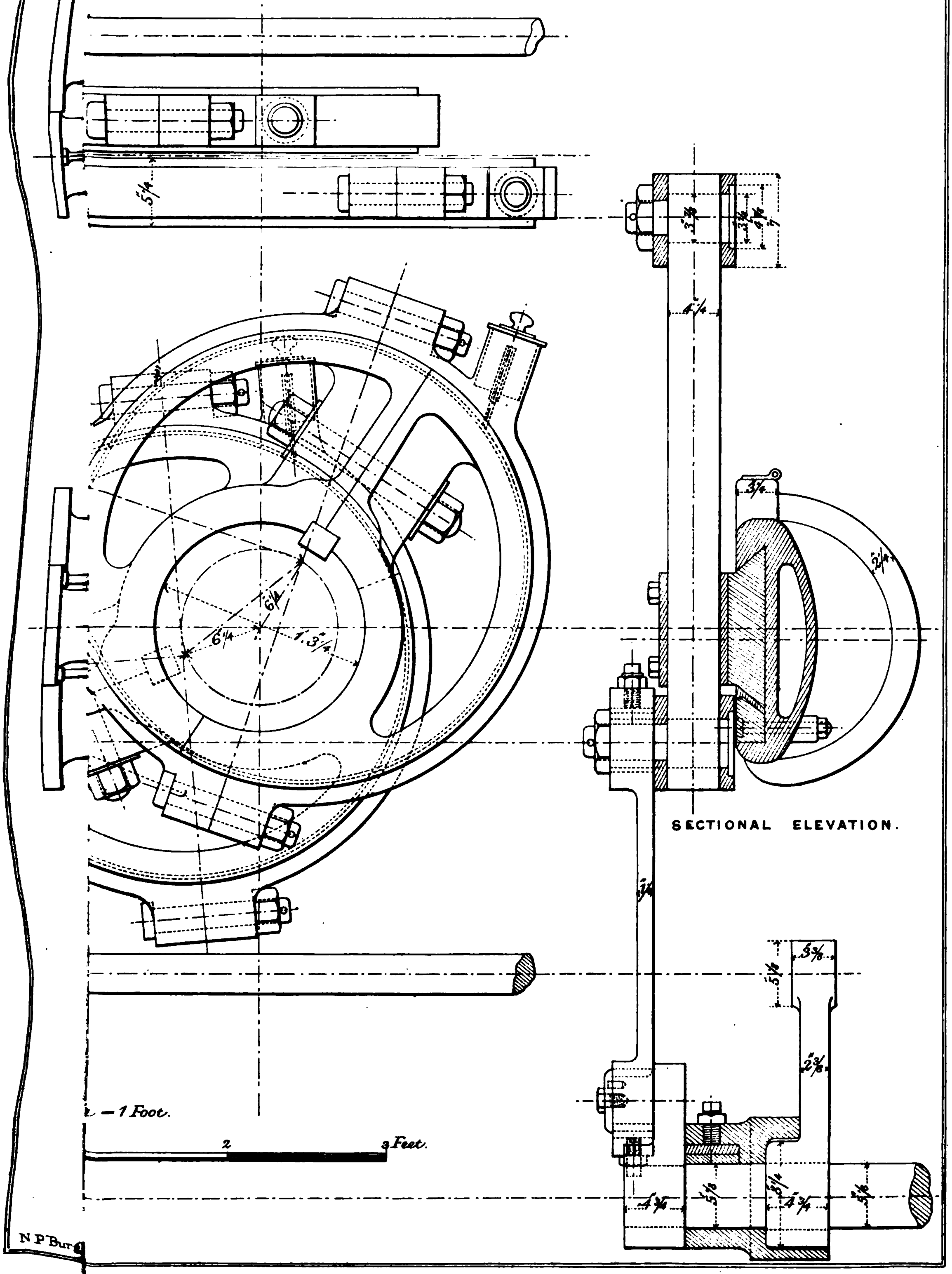
Scale ½ Inch—1 Foot.

N P Burgh. Direx

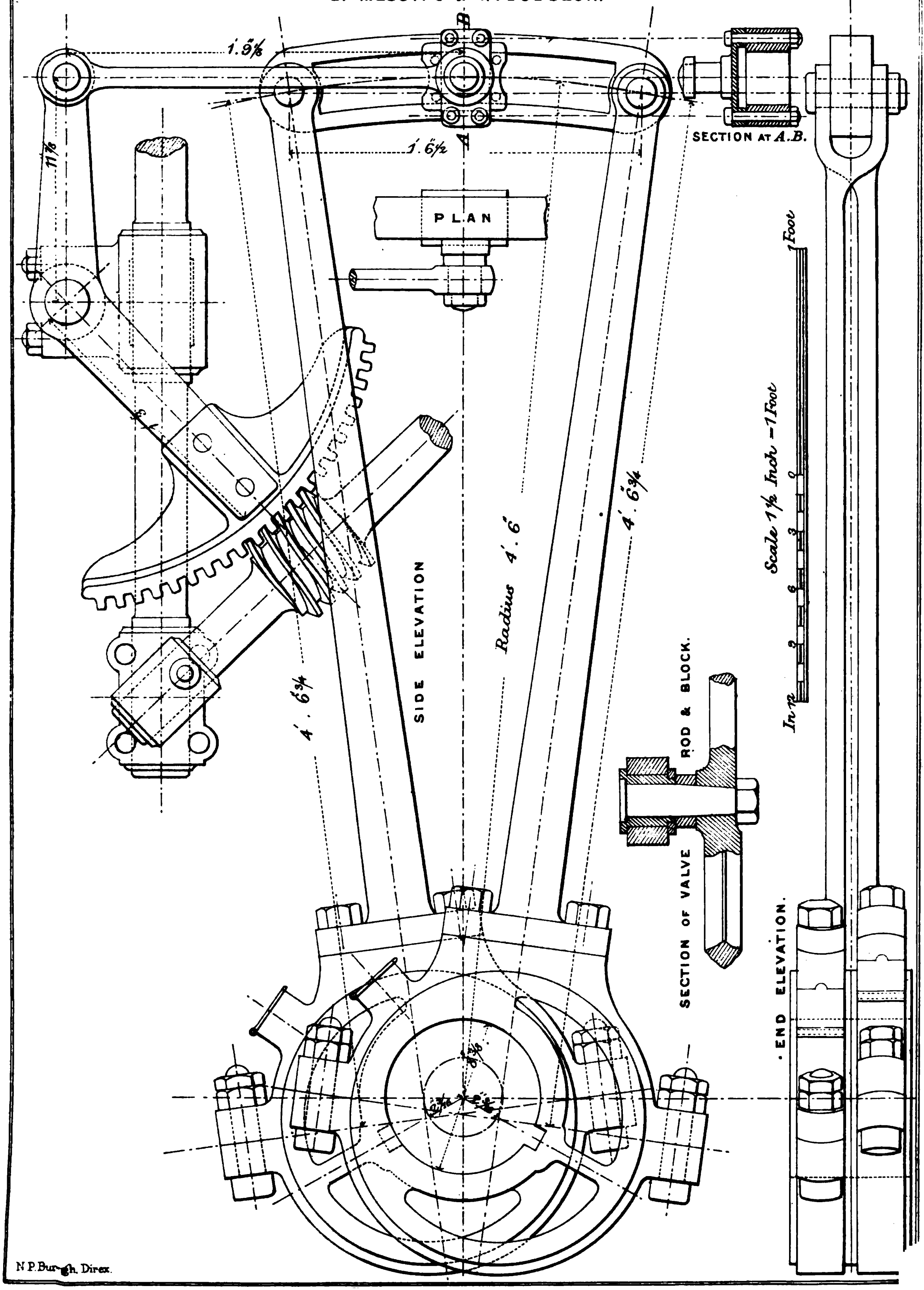
E. & F. N. Spon, 48, Charing Cross, London

Plate 21.

TION BY MESSRS HUMPHRYS, TENNANT & Co 1870.



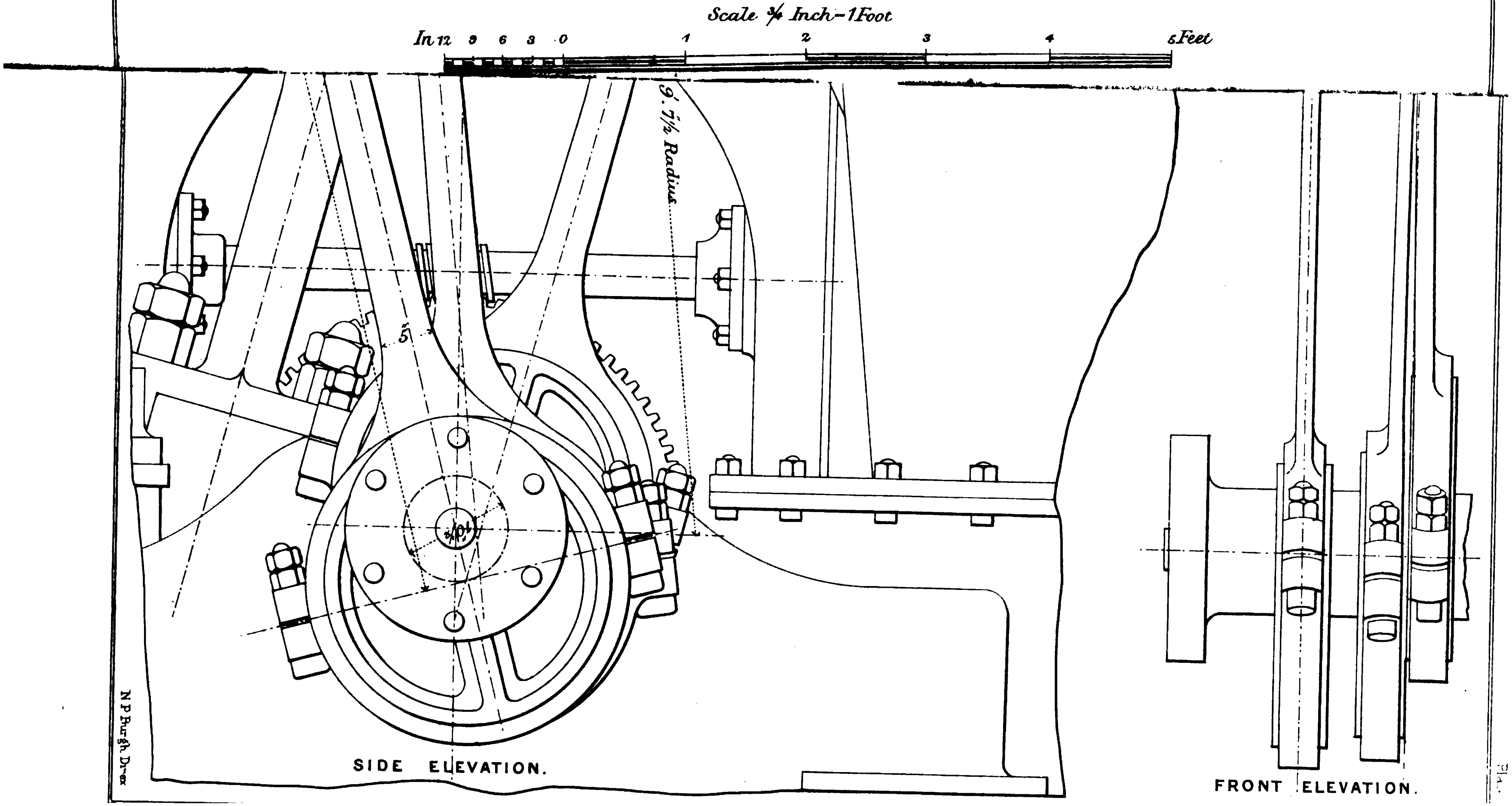
LINK MOTION & REVERSING GEAR.
FITTED IN H.M.S. "ABYSSINIA" TWIN SCREW ENGINES. 200 HP. NOML. COLLY
BY MESSRS. J & W. DUDGEON.



N P Burgh, Direx.

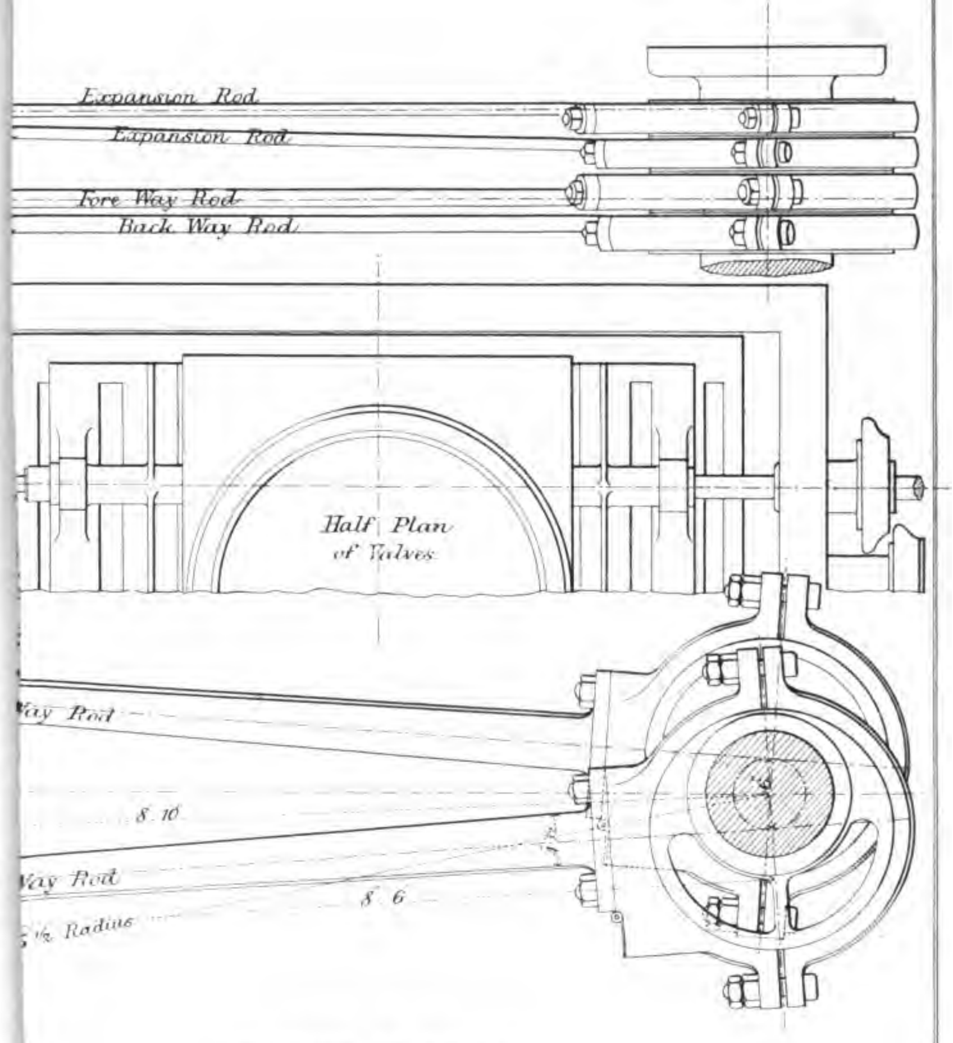
LINK MOTION, AND EXPANSION GEAR, OF THE ENGINES. FITTED IN W. I. M. S. "COLUMBIAN." 300 HP. NOML. COLLY.

BY G. W. JAFFREY, FOR THOS. RICHARDSON & SONS.

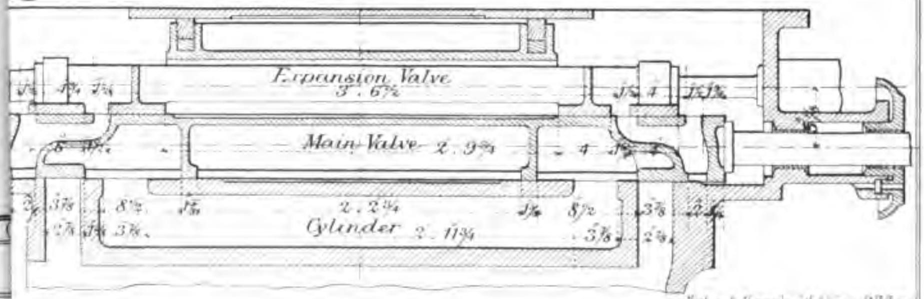


LINK MOTION, EXPANSION GEAR, SLIDE VALVE AND REVERSING GEAR OF THE ENGINES.

FITTED IN S.S. "NEERA". 180 HP. NOML. COLLY.



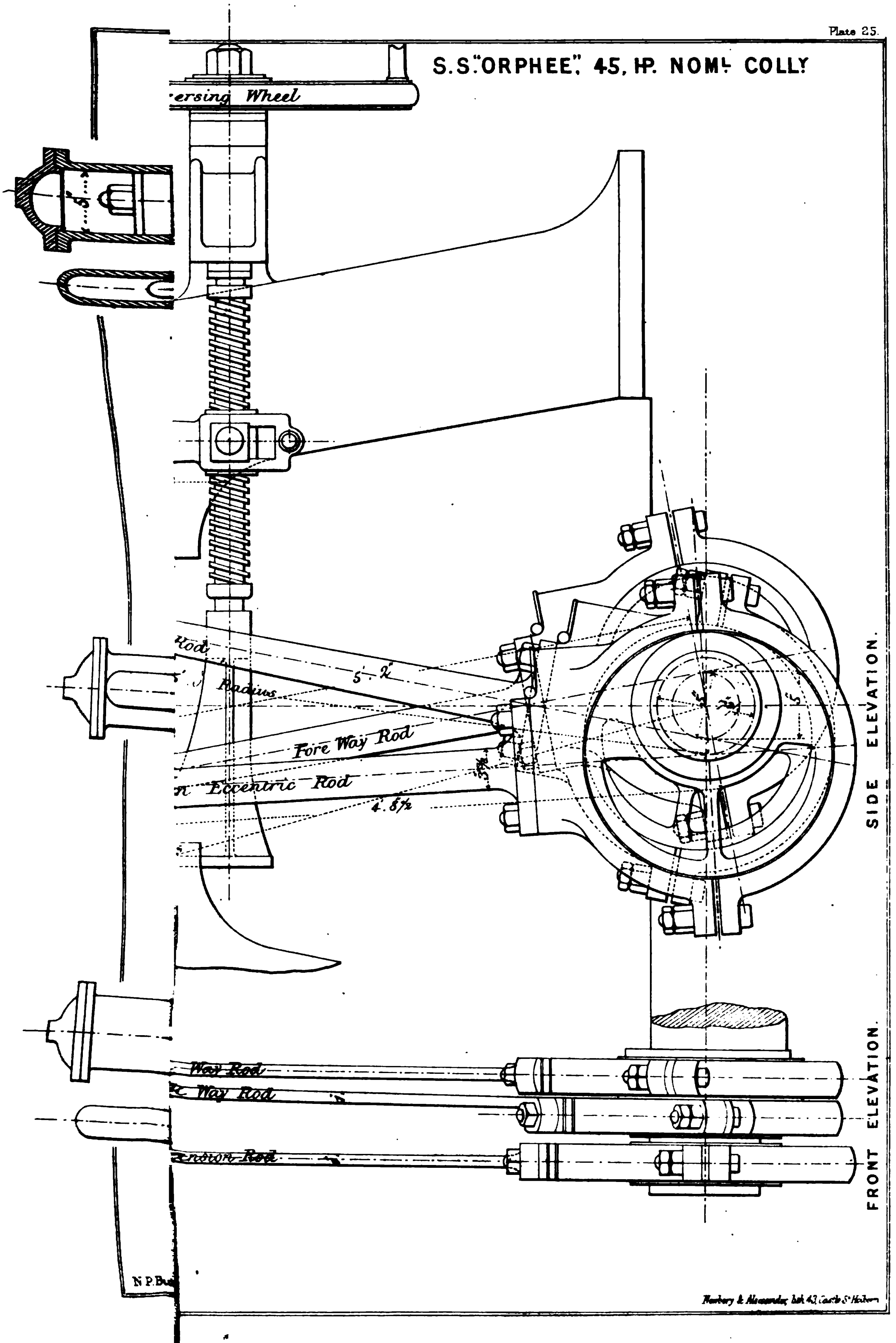
SECTION OF VALVES.



N.P. Burgh Direx.

Newbury & Alexander Lith 43 Castle St Holborn

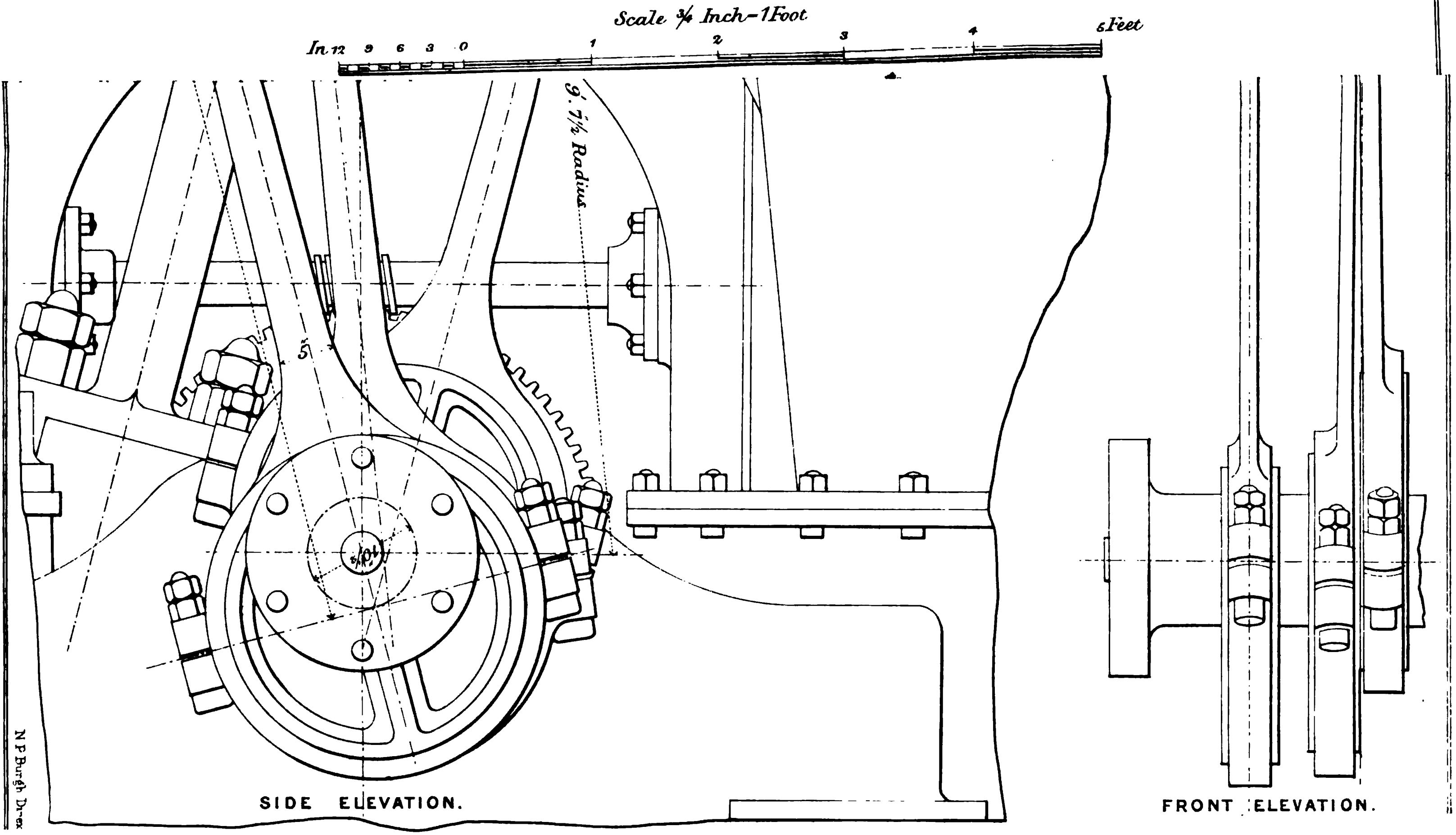
S.S. "ORPHEE". 45. HP. NOML. COLLY.



Newbery & Alexander, lith 43, Castle St Holborn

LINK MOTION, AND EXPANSION GEAR, OF THE ENGINES. FITTED IN W. I. M. S. "COLUMBIAN." 300 HP. NOML. COLLY.

BY G. W. JAFFREY. FOR THOS. RICHARDSON & SONS.



SIDE ELEVATION.

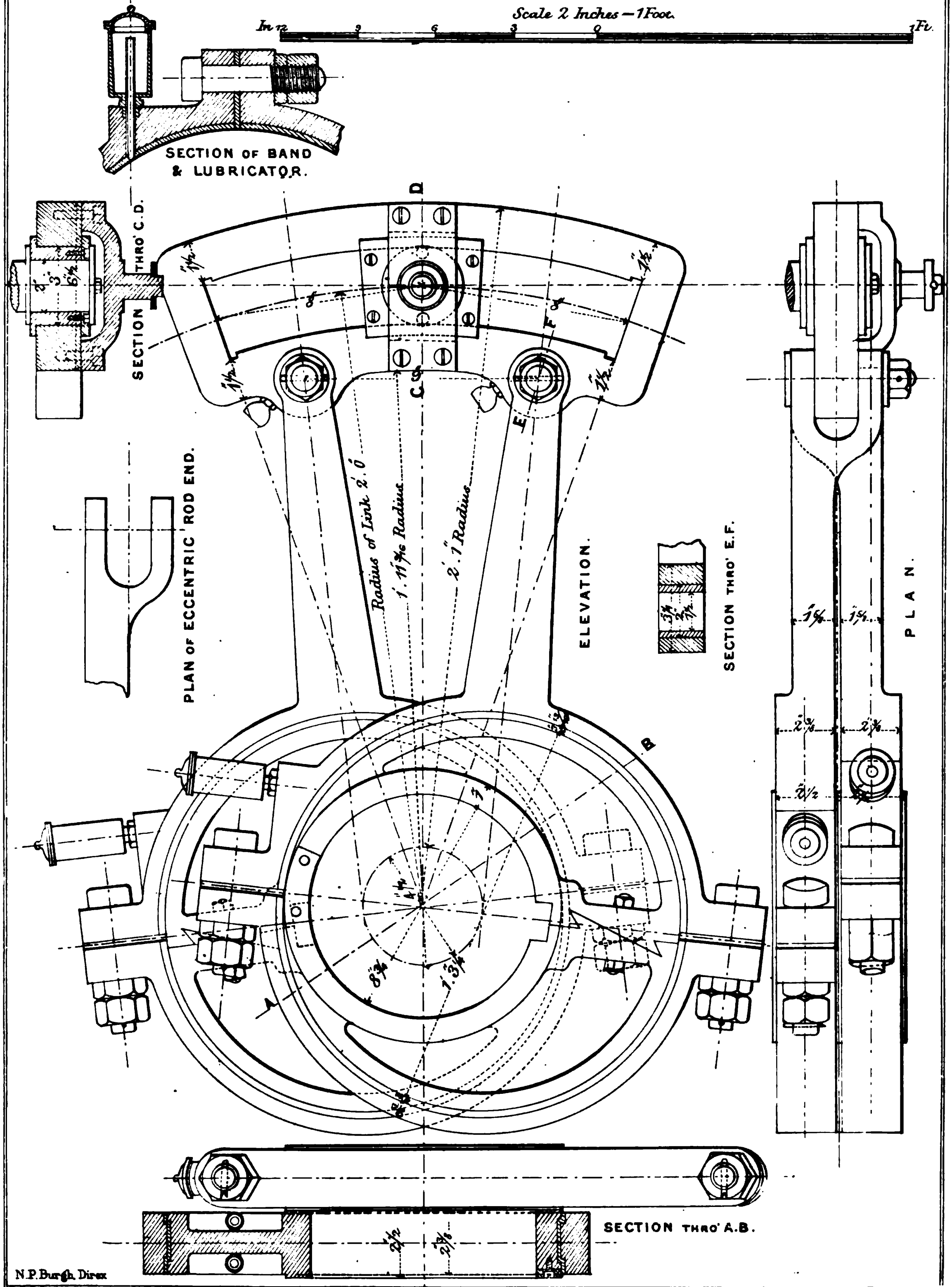
FRONT ELEVATION.

N P Burgh Dr-ex

DETAILS OF LINK MOTION OF TWIN-SCREW ENGINES FITTED IN S.S. "R.N." NOM^L, COLL^Y,

BY N.P. BURGH.

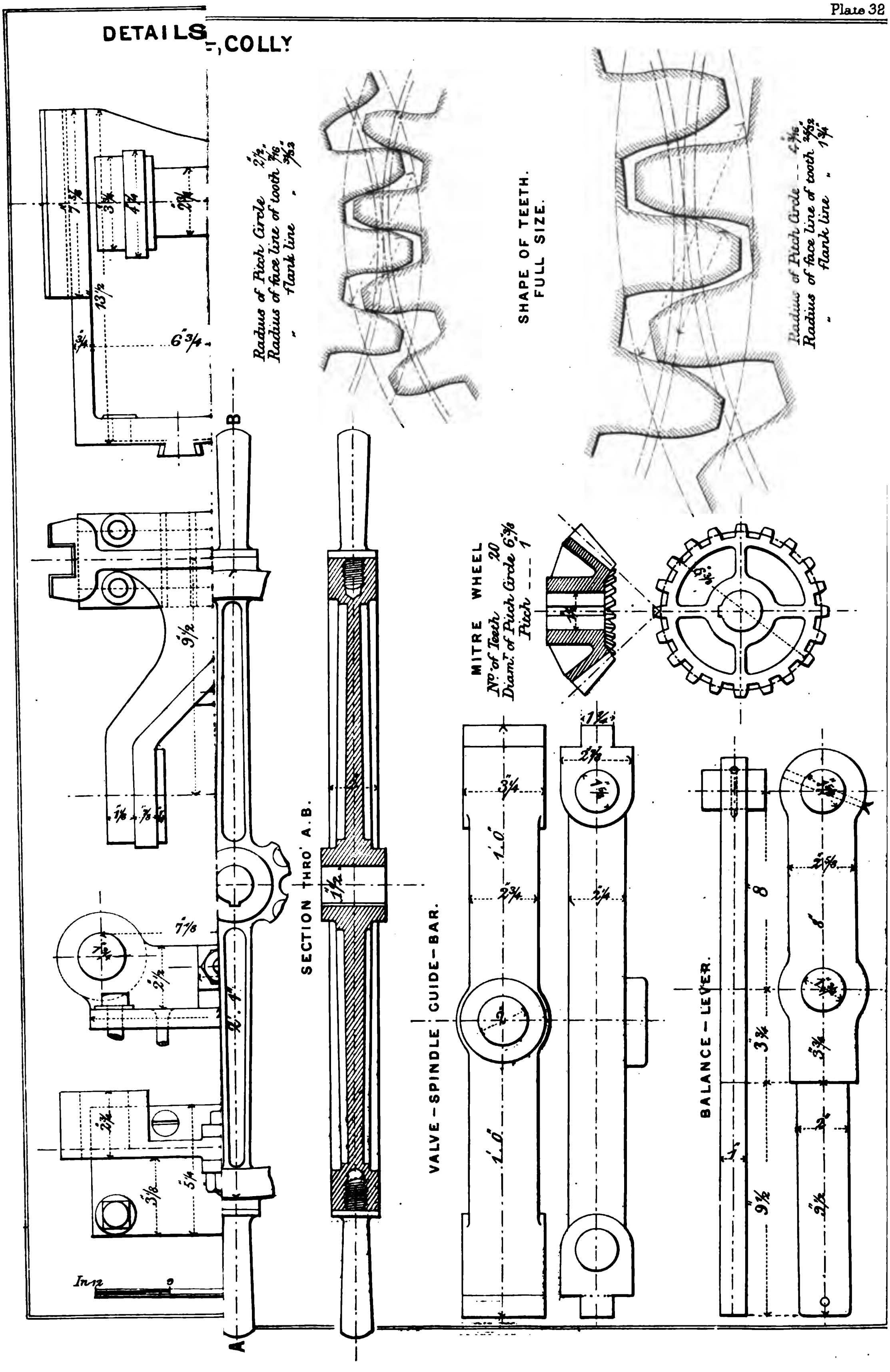
Scale 2 Inches — 1 Foot.



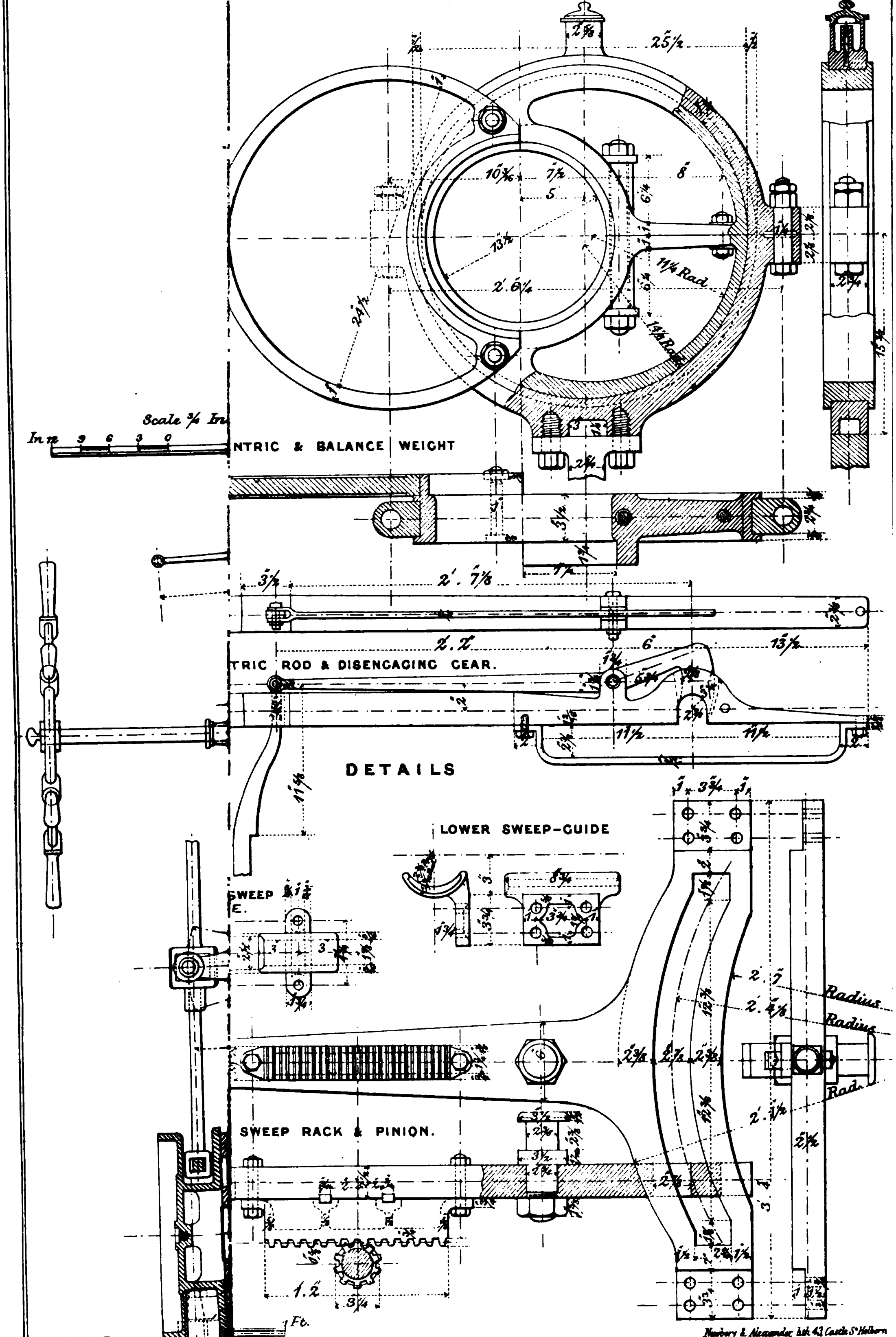
N.P. Burgh, Direx

E. & F. N. Spon, 48, Charing Cross, London

DETAILS


COLLY
SHAPE OF TEETH.
FULL SIZE.
Radius of Pitch Circle 2½"
Radius of face line of tooth 7/16"
" flank line " 3/32"
Radius of Pitch Circle 4 3/16"
Radius of face line of tooth 25/32"
" flank line " 1¾"
MITRE WHEEL
No. of Teeth 20
Diamr. of Pitch Circle 6⅜
Pitch 1
SECTION THRO' A.B.
VALVE-SPINDLE GUIDE-BAR.
BALANCE-LEVER.
A
B
7¾
3¼
4½
2¾
13½
6¾
¾
9½
1⅛
⅞
7⅞
2½
2¼
5⅛
5¼
2' 4"
1½
1' 0"
3¼
2¾
2
1⅞
2⅝
1¼
2¼
2⅝
8
8
3¾
3¾
2
1
9½
2½
In 12

ENGINES OF 250 HP. NOML. COLLY. 1870.



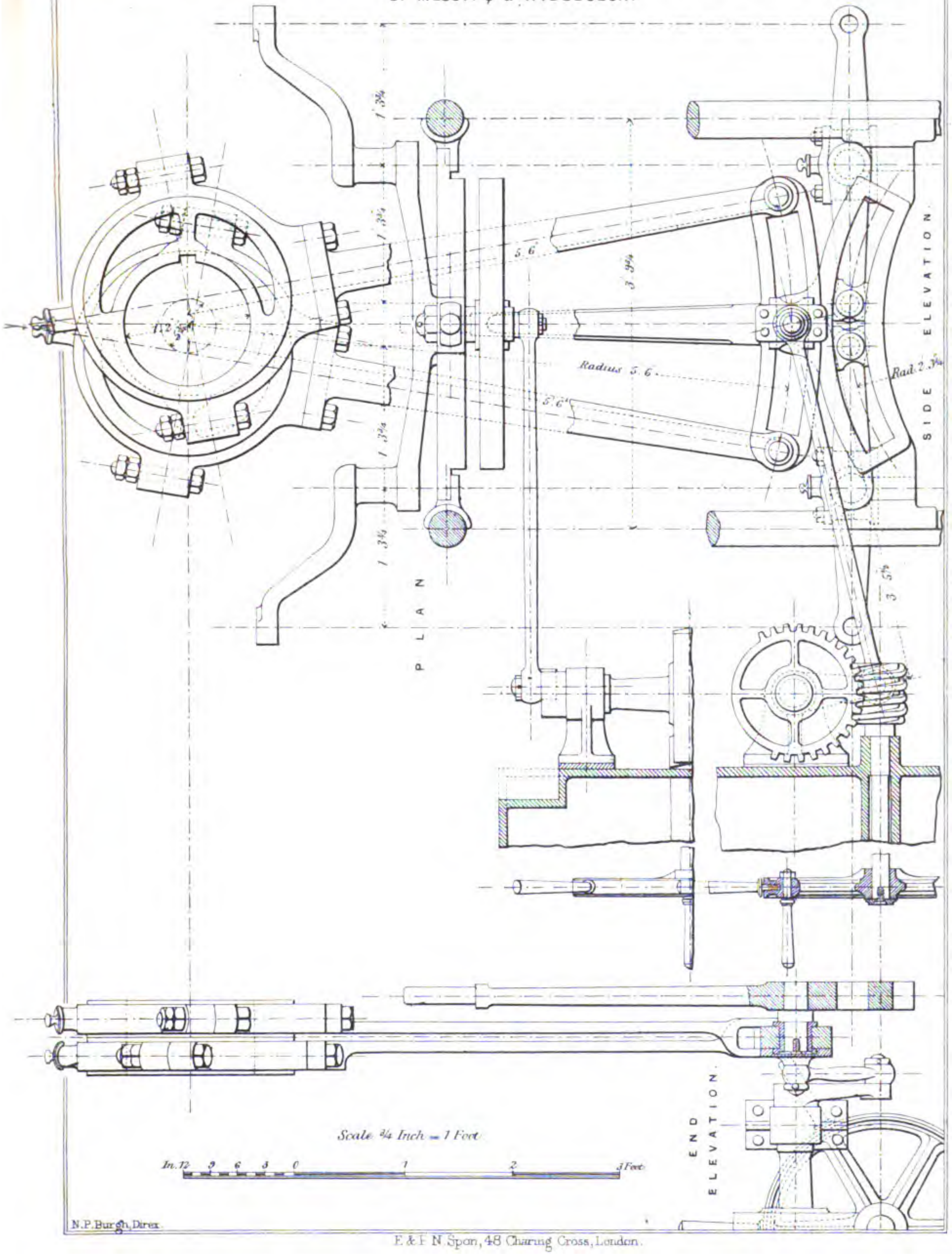
N.P. Burgh. Direx.

Newbury & Alexander, lith 43 Castle St Holborn

Plate 33 B.

ARRANGEMENT OF LINK MOTION & REVERSING GEAR OF OSCILLATING ENGINES OF 200 HP. NOML COLLY

BY MESSRS J & W. DUDGEON.



Scale ¾ Inch = 1 Foot

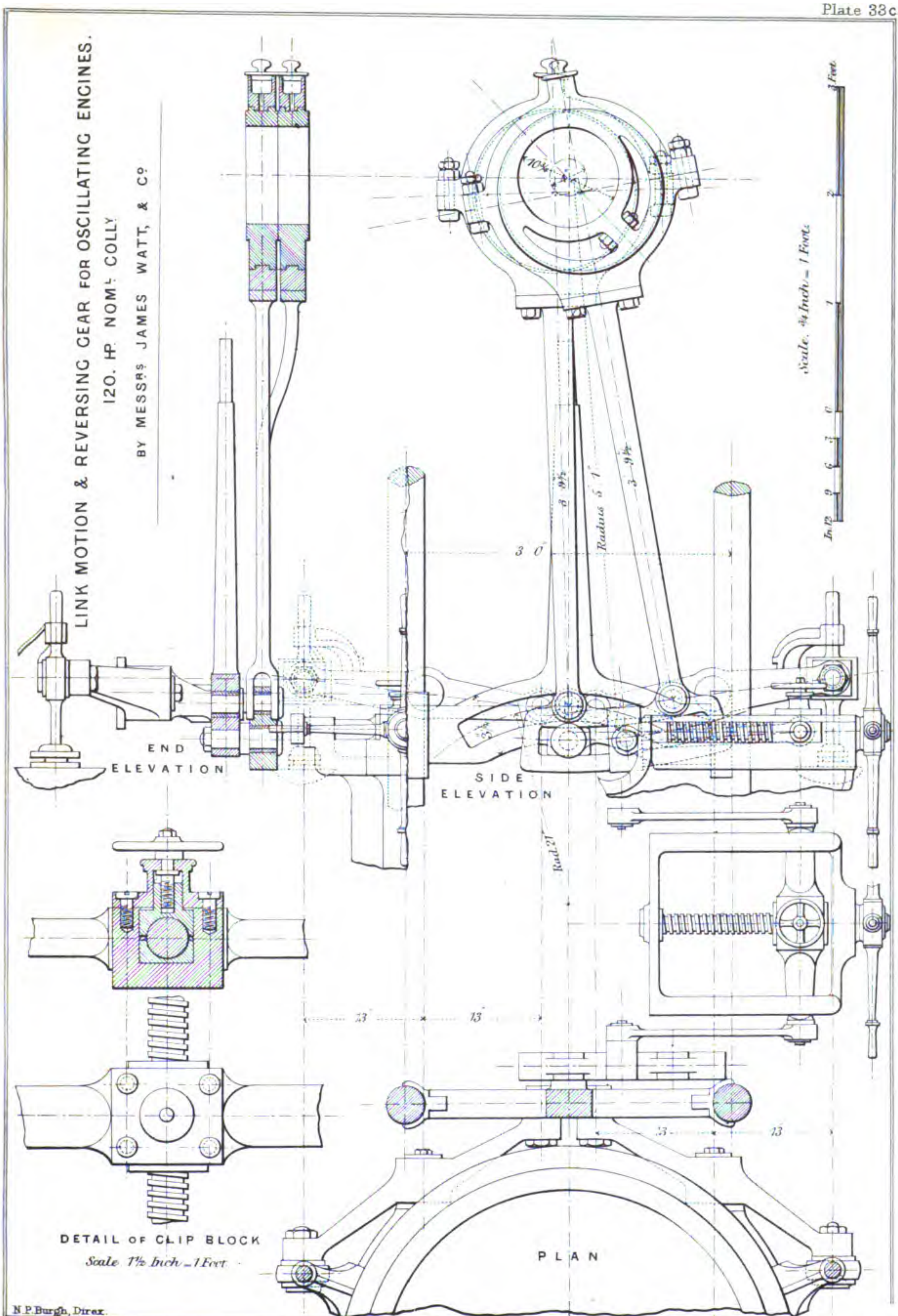
N.P. Burgh, Direx.

E & F N. Spon, 48 Charing Cross, London.

LINK MOTION & REVERSING GEAR FOR OSCILLATING ENGINES.

120. HP. NOML. COLLY.

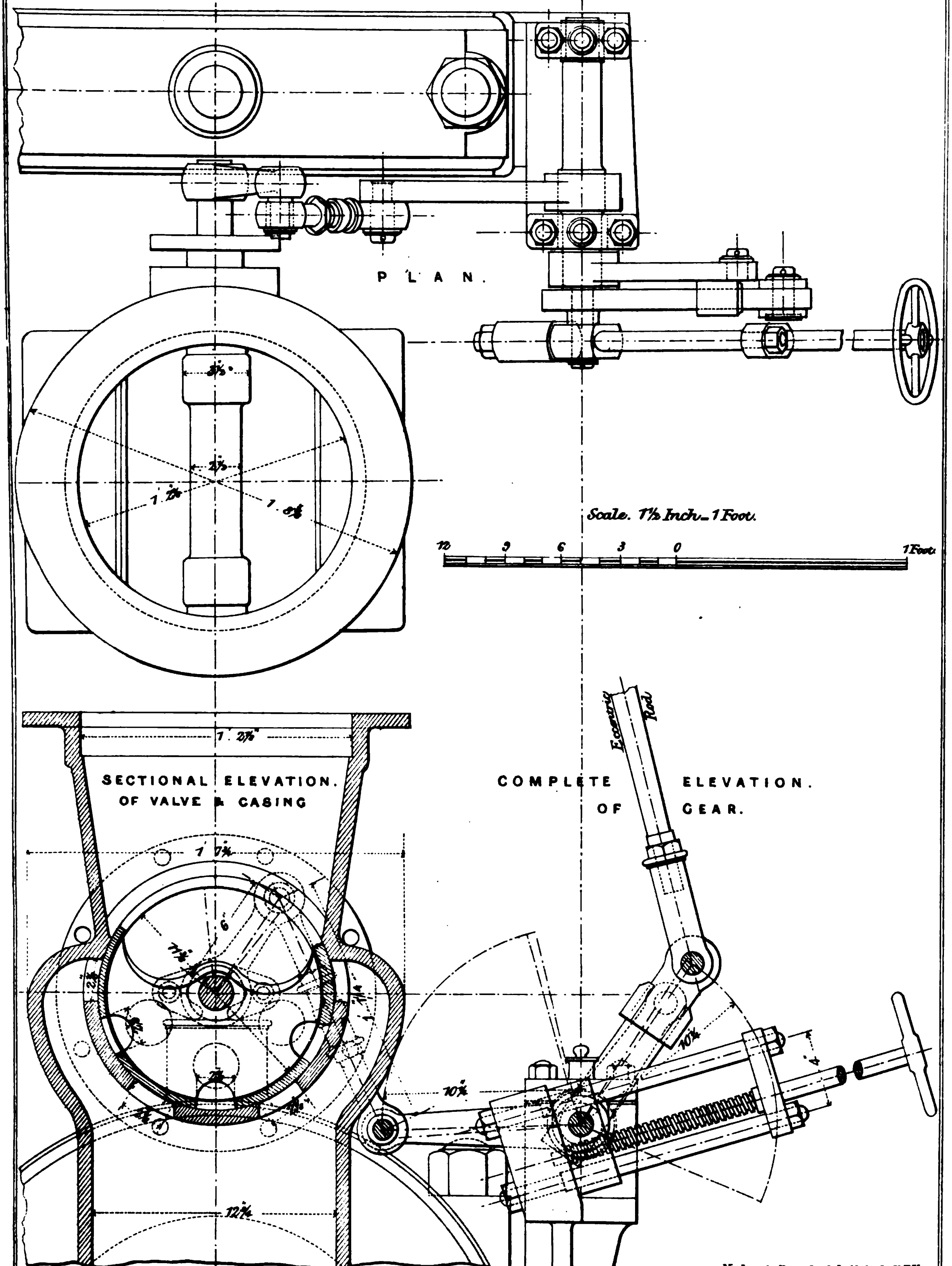
BY MESSRS. JAMES WATT, & Co.



N. P. Burgh, Direx.

E & F N Spon, 48 Charing Cross, London.

EXPANSION GEAR FOR OSCILLATING ENGINES BY MESSRS MAUDSLAY SONS & FIELD.

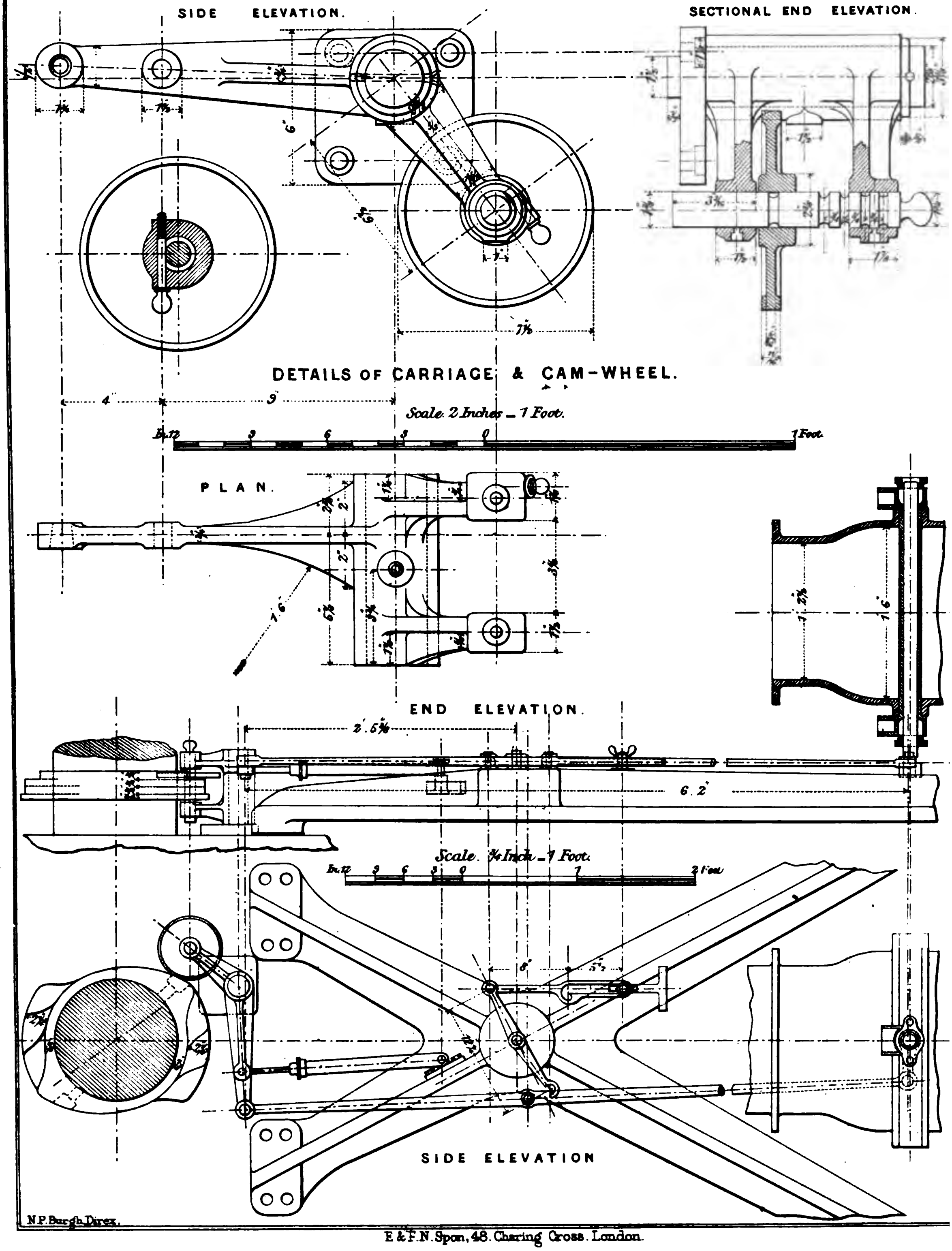


Newbery & Alexander, lith. 43, Castle St Holborn.

E & F. N. Spon. 48. Charing Cross, London.

GENERAL CAM-EXPANSION GEAR FOR OSCILLATING PADDLE-WHEEL ENGINES.

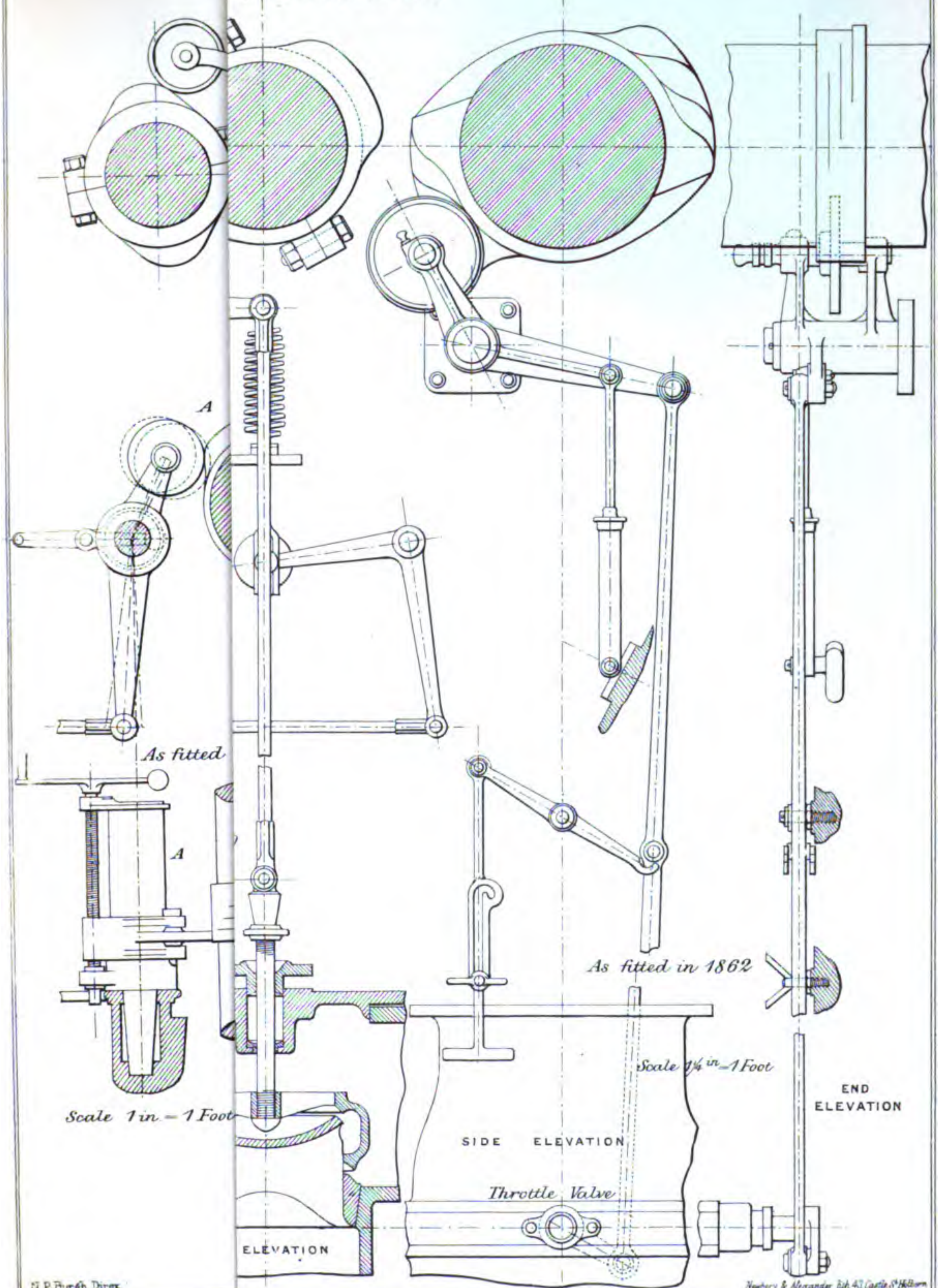
250 HP. NOML. COLLY. 1870.



N.P. Burgh Direx.

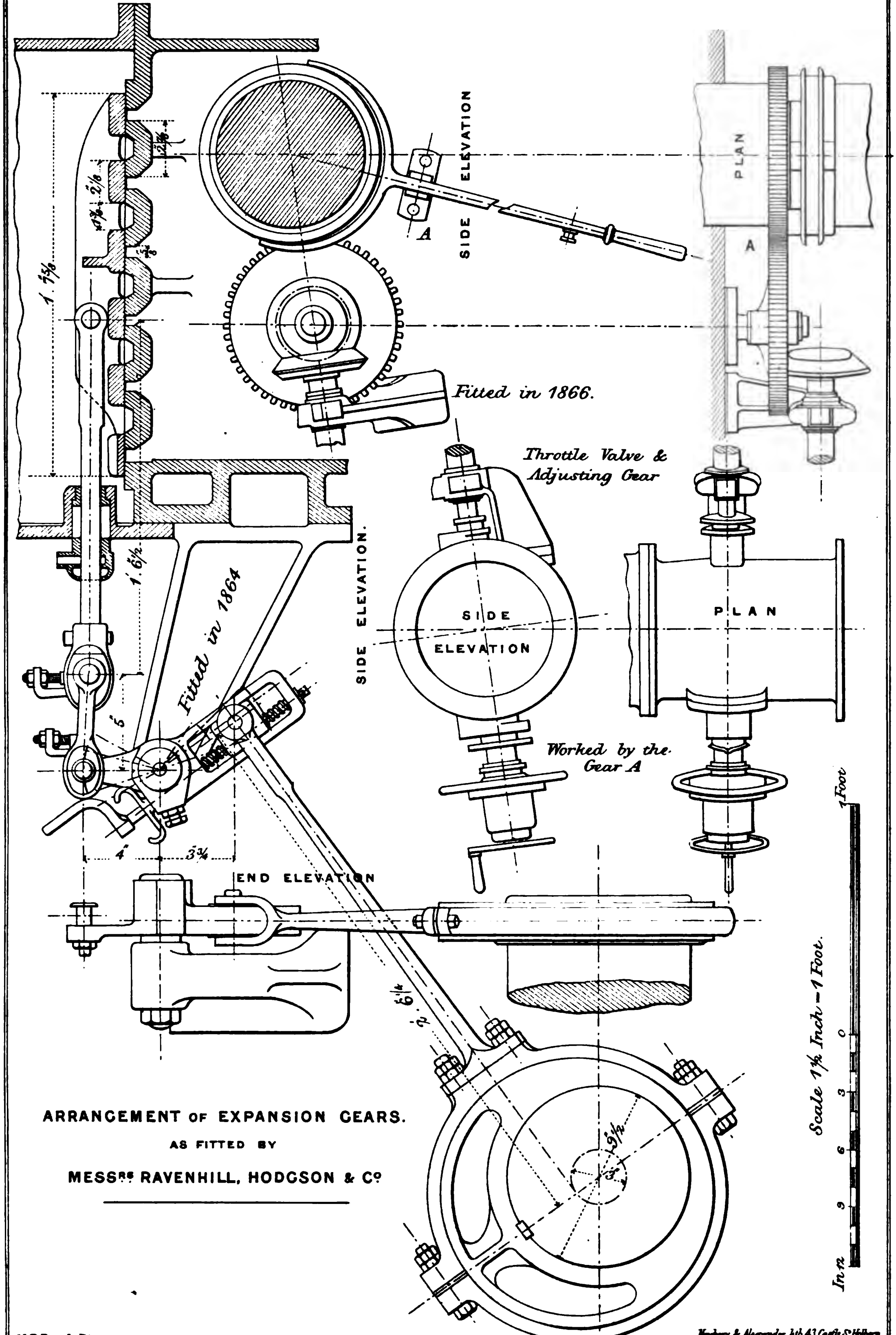
E & F.N. Spon, 48. Charing Cross. London.

L, HODGSON & Cº



N P Burgh. Direx.

Newbery & Alexander, lith 43 Castle Sᵗ Holborn



ARRANGEMENT OF EXPANSION GEARS.

AS FITTED BY

MESSRS RAVENHILL, HODGSON & Co

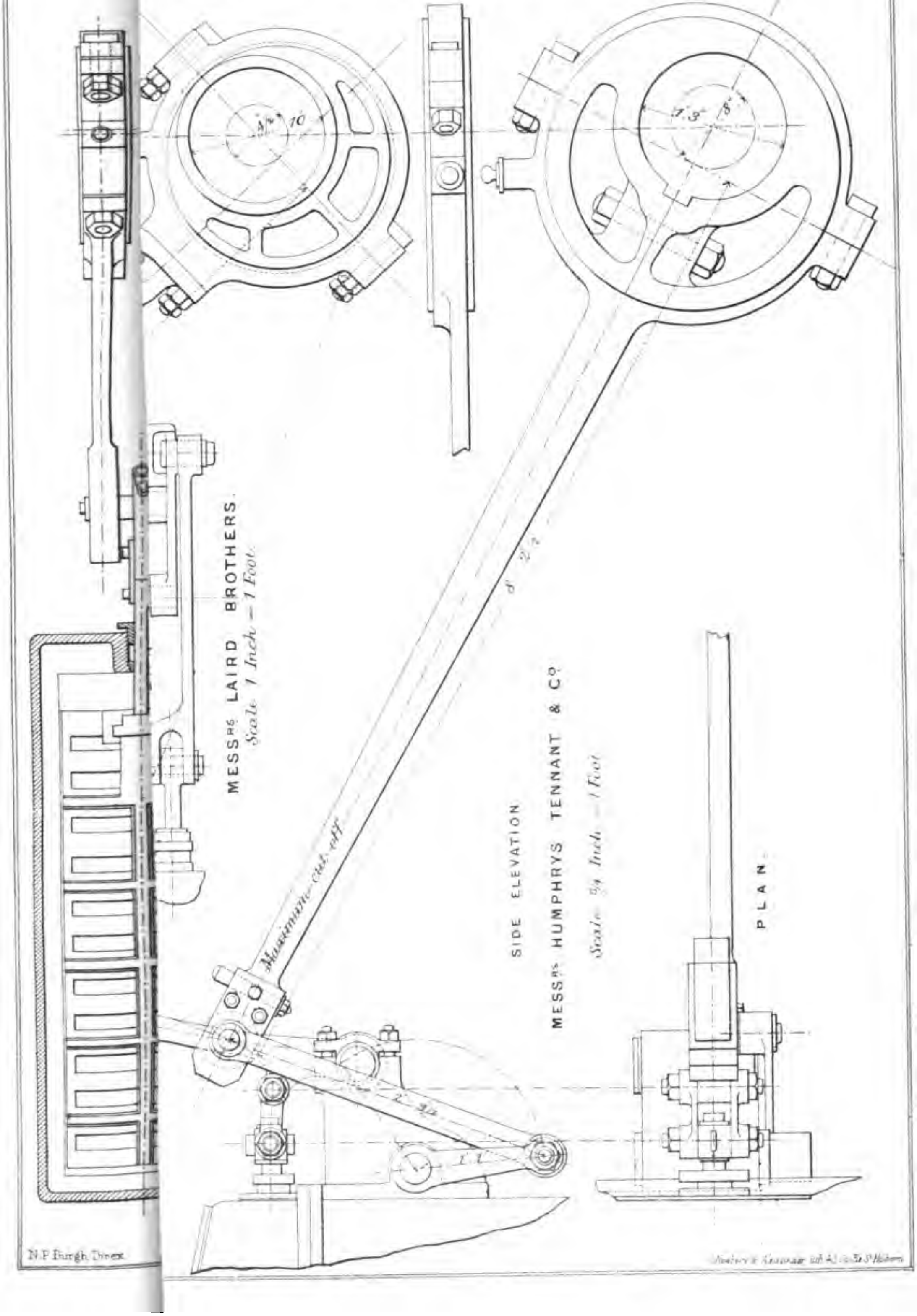
N P Burgh. Direx

Newbury & Alexander, lith 43 Castle St Holborn

E & F N Spon, 48, Charing Cross, London.

Plate 36.

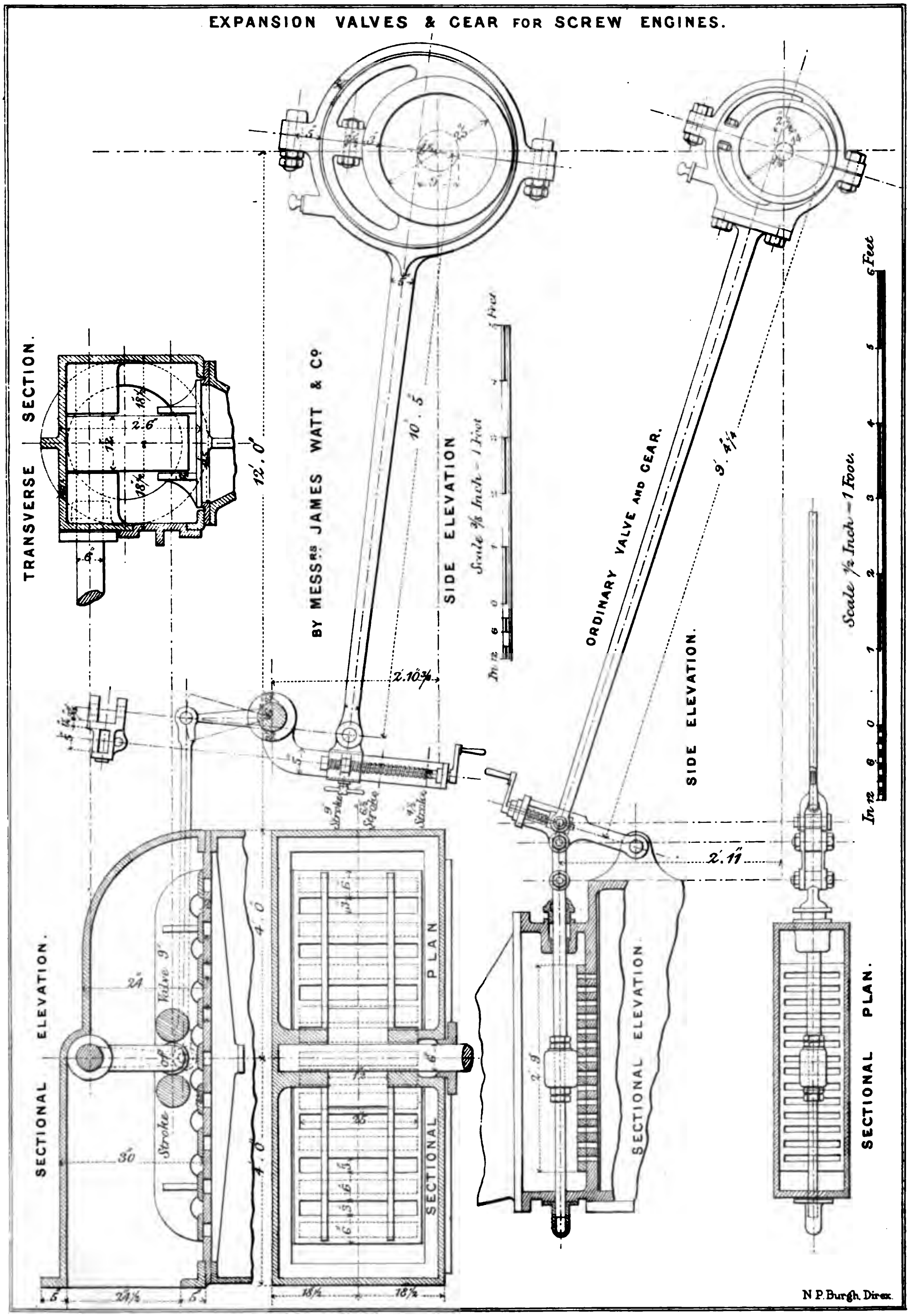
ES AS USED IN THE YEAR 1870.



N. P. Burgh Direx.

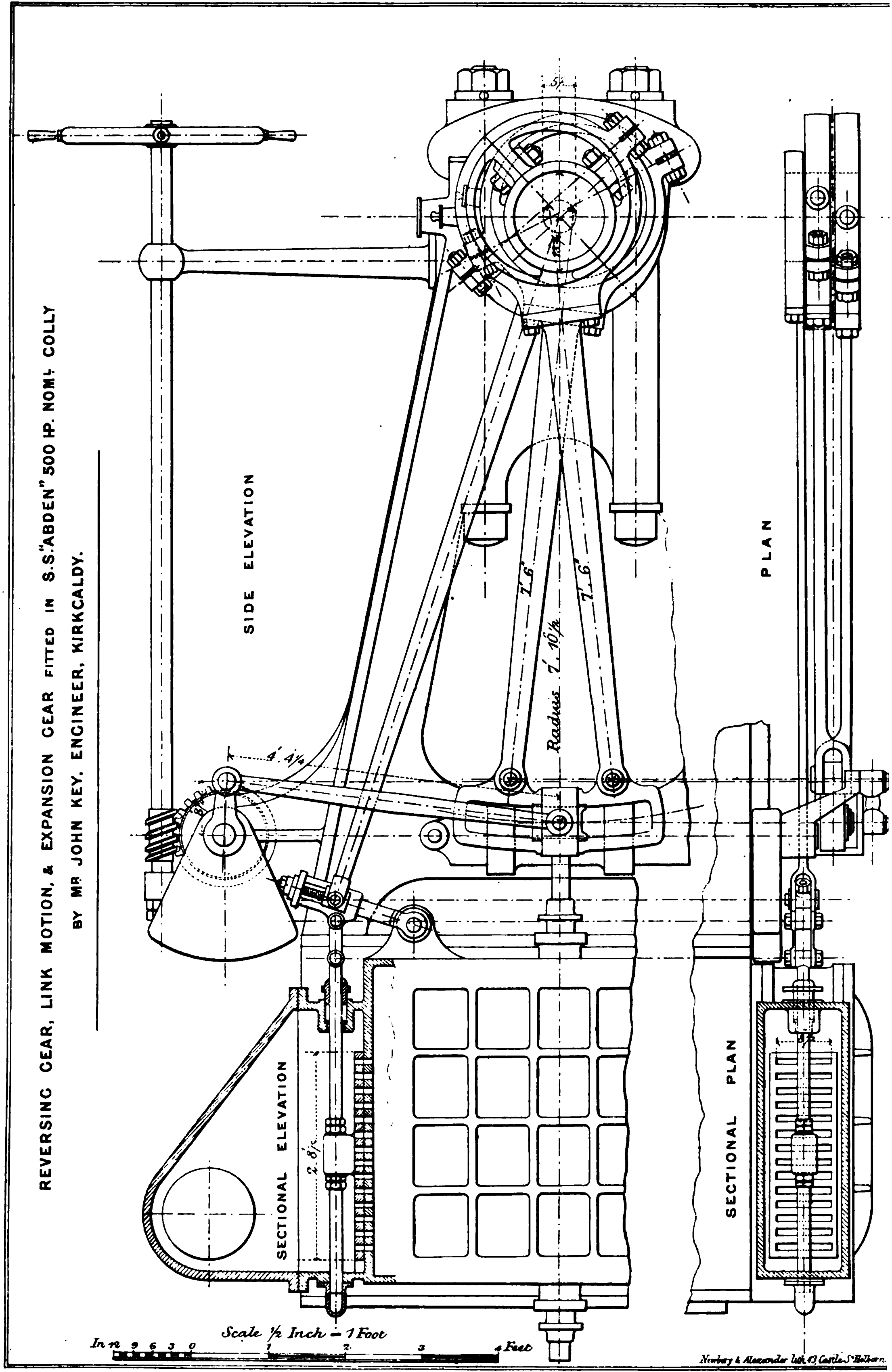
[illegible] lith. 41 [illegible] St Holborn

EXPANSION VALVES & GEAR FOR SCREW ENGINES.



N P Burgh, Direx.

E & F N Spon, 48, Charing Cross, London



REVERSING GEAR, LINK MOTION, & EXPANSION GEAR FITTED IN S.S. "ABDEN" 500 HP. NOML. COLLY

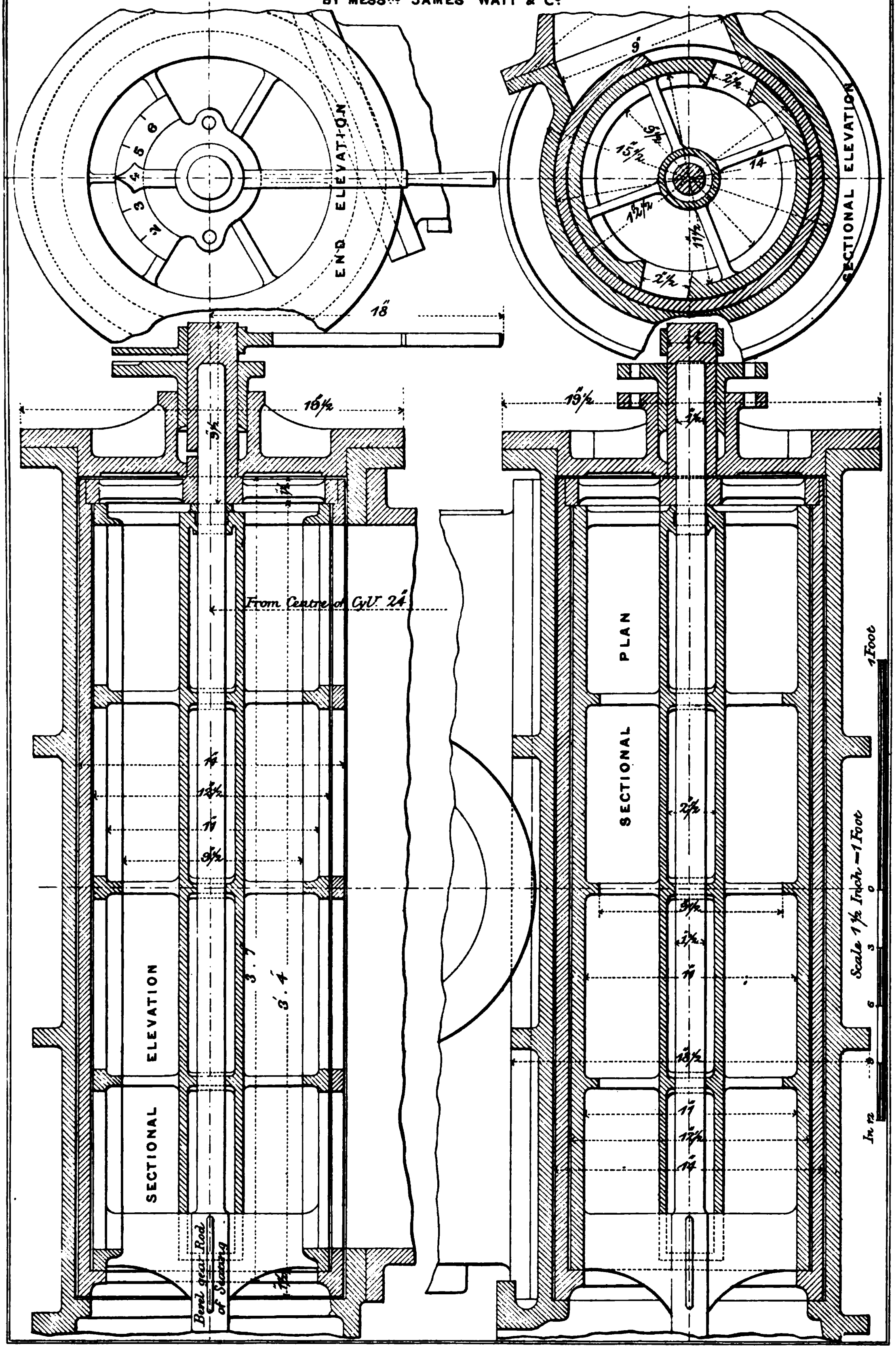
BY MR JOHN KEY, ENGINEER, KIRKCALDY.

Newbury & Alexander lith, 43 Castle St Holborn.

E & F N Spon 48 Charing Cross, London.

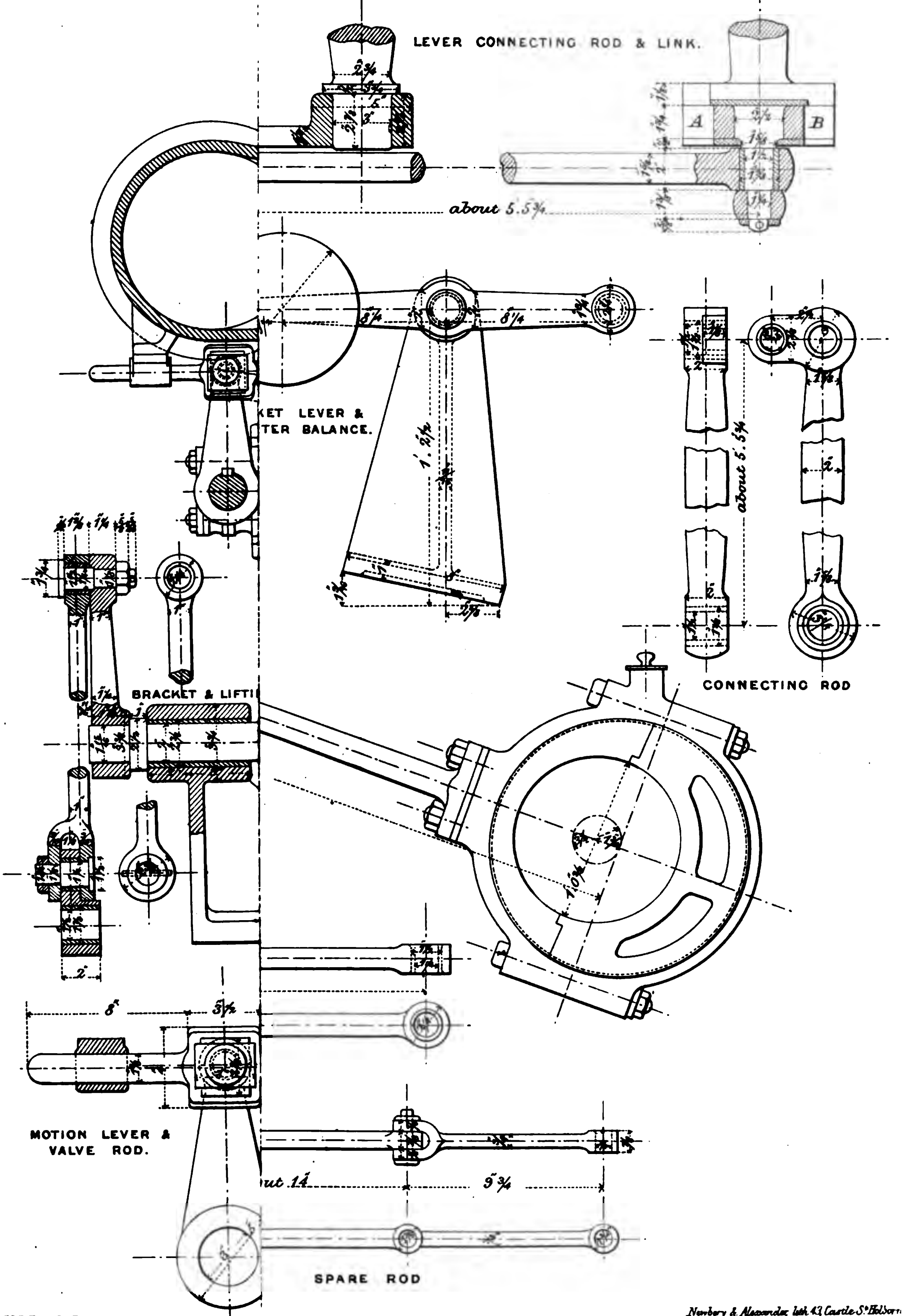
REVOLVING SEATING & STATIONARY CYLINDRICAL EXPANSION VALVE.

BY MESSRS JAMES WATT & Co



E. & F N Spon 48, Charing Cross, London.

EH" 350 HP NOML COLLY



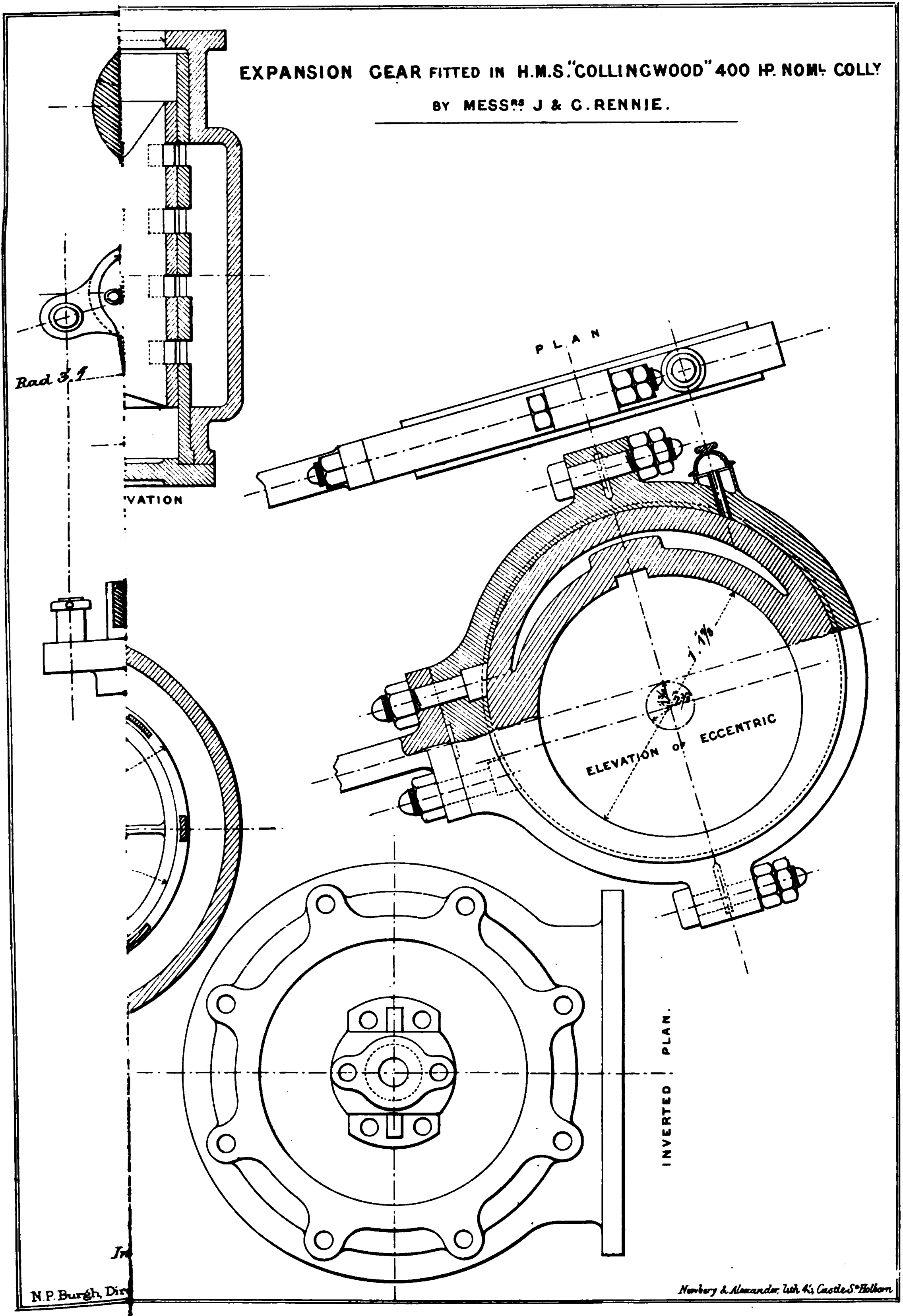
N.P. Burgh, Direx.

Newbery & Alexander, lith 43 Castle St Holborn

Plate 39 A.

EXPANSION GEAR FITTED IN H.M.S. "COLLINGWOOD" 400 H.P. NOM^L. COLL^Y

BY MESS^RS J & G. RENNIE.



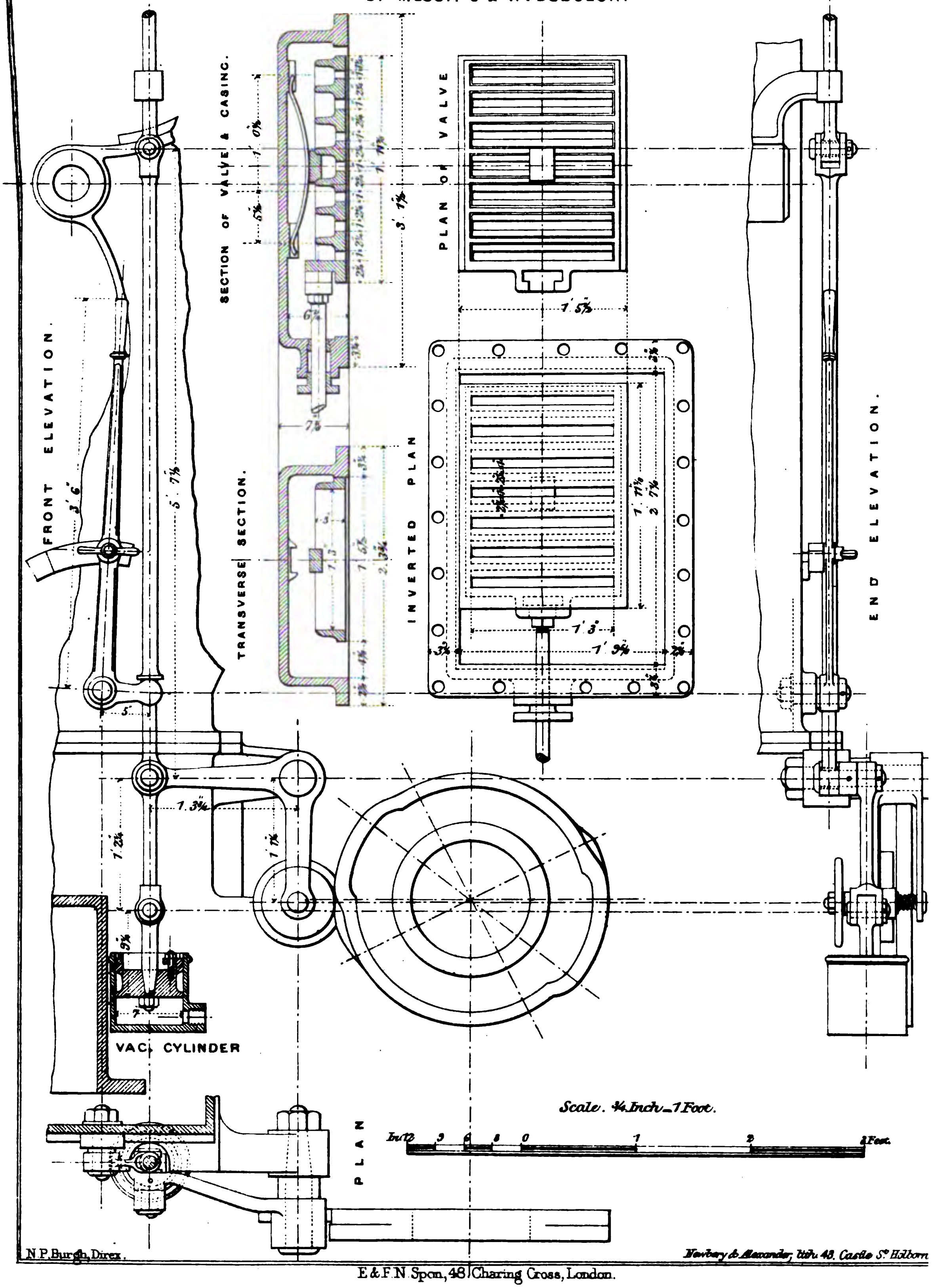
N.P. Burgh, Dir

Newbury & Alexander, lith 4½ Castle S^t Holborn

Plate 39

ARRANGEMENT OF EXPANSION GEAR & VALVE FOR VERTICAL INVERTED ENGINES 200 HP. NOML. COLLY

BY MESSRS. J & W. DUDGEON.

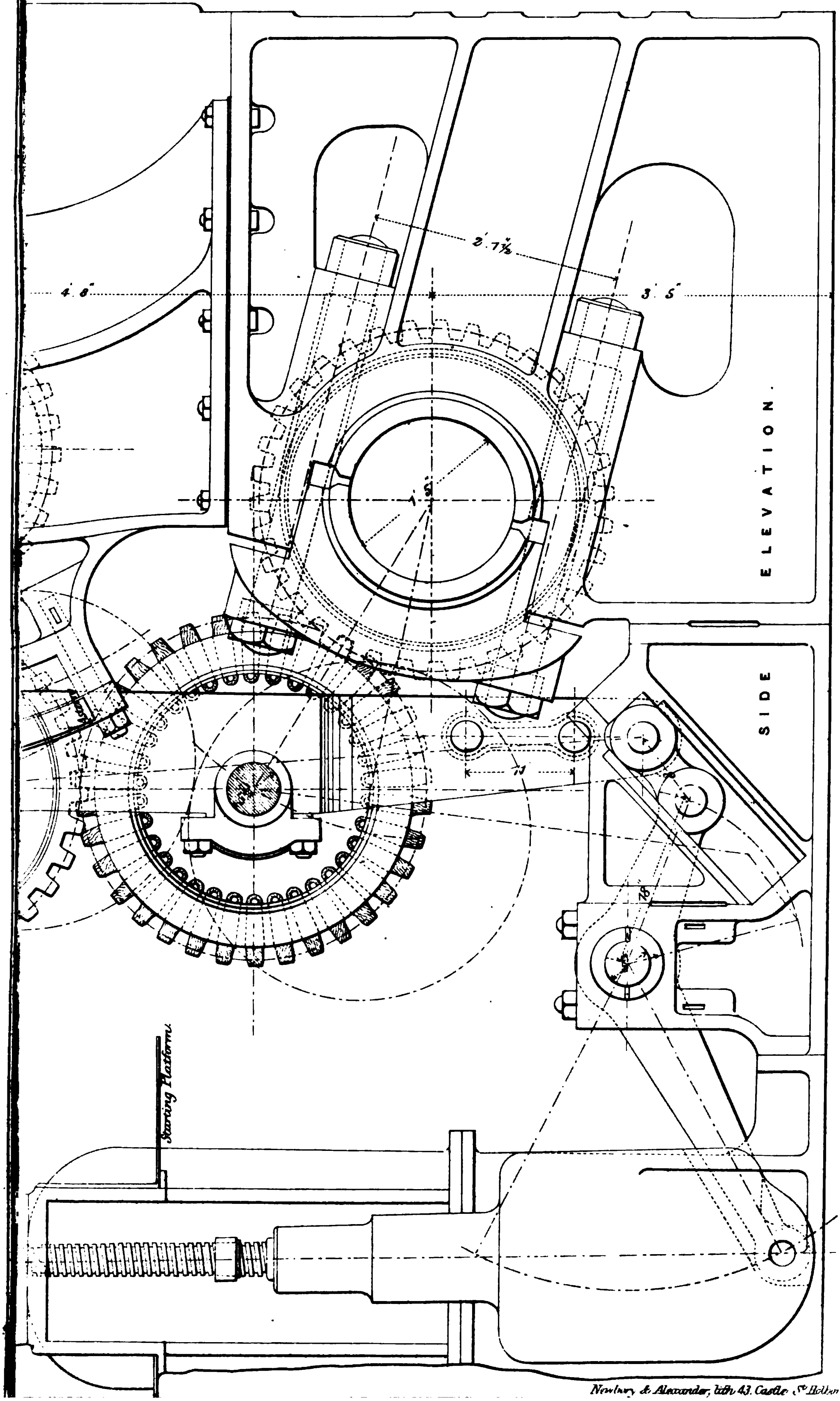


N.P. Burgh, Direx.

Newbery & Alexander, lith. 48, Castle St. Holborn

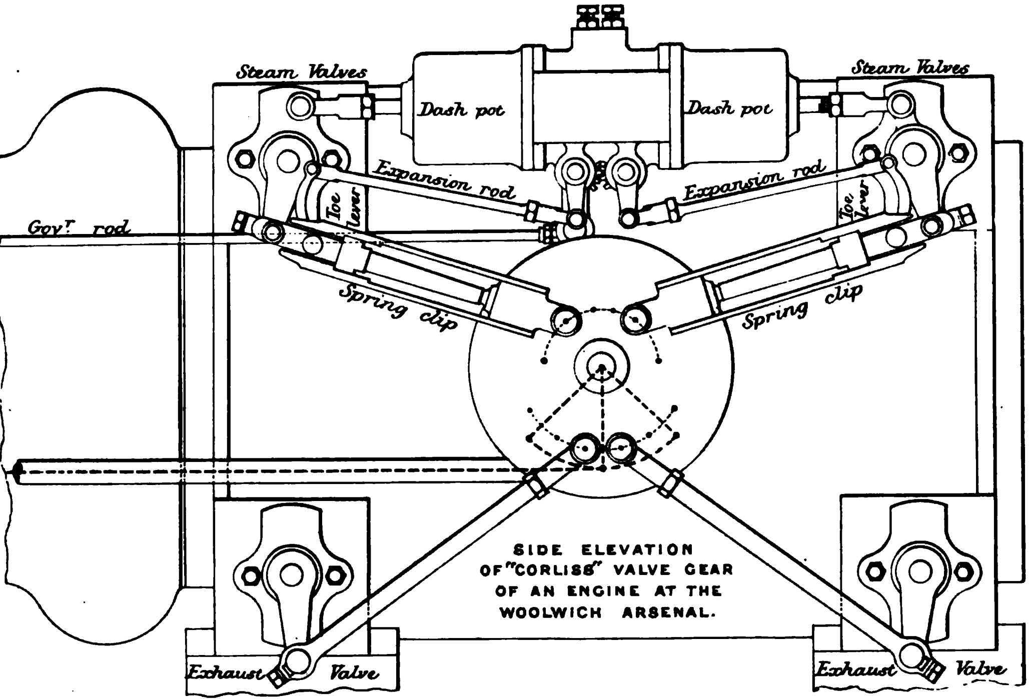
E & F. N. Spon, 48 Charing Cross, London.

IOML COLLY BY MESSRS MAUDSLAY SONS & FIELD.

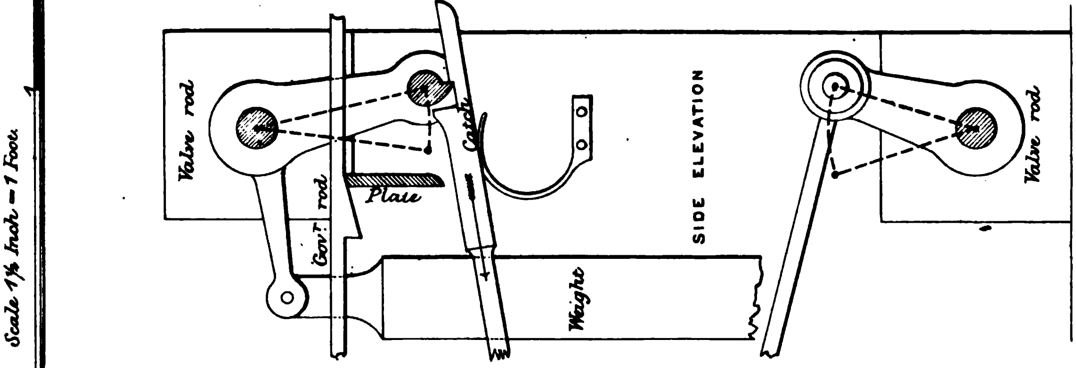


Newbury & Alexander, lith 43, Castle St Holborn

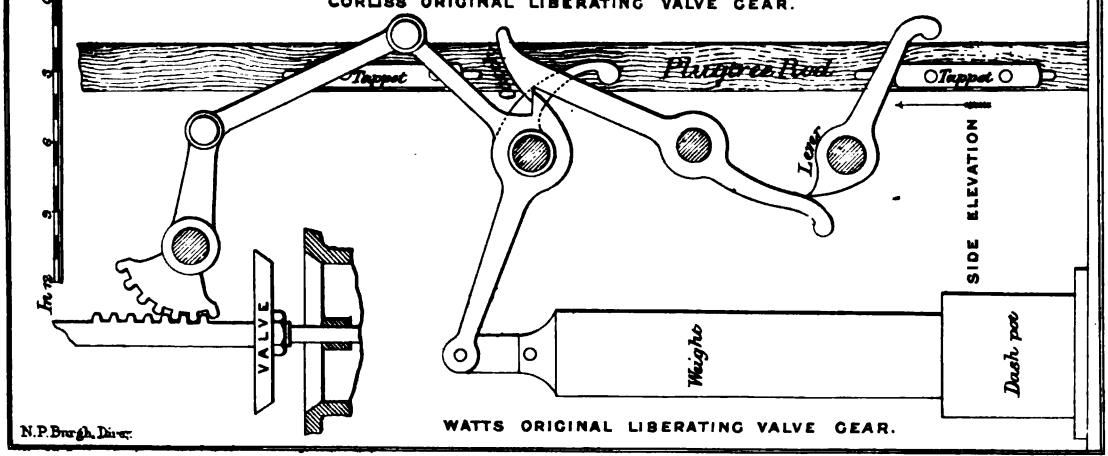
ORIGINAL AND MODERN "CORLISS" VALVE GEARS.



SIDE ELEVATION OF "CORLISS" VALVE GEAR OF AN ENGINE AT THE WOOLWICH ARSENAL.



CORLISS'S ORIGINAL LIBERATING VALVE GEAR.

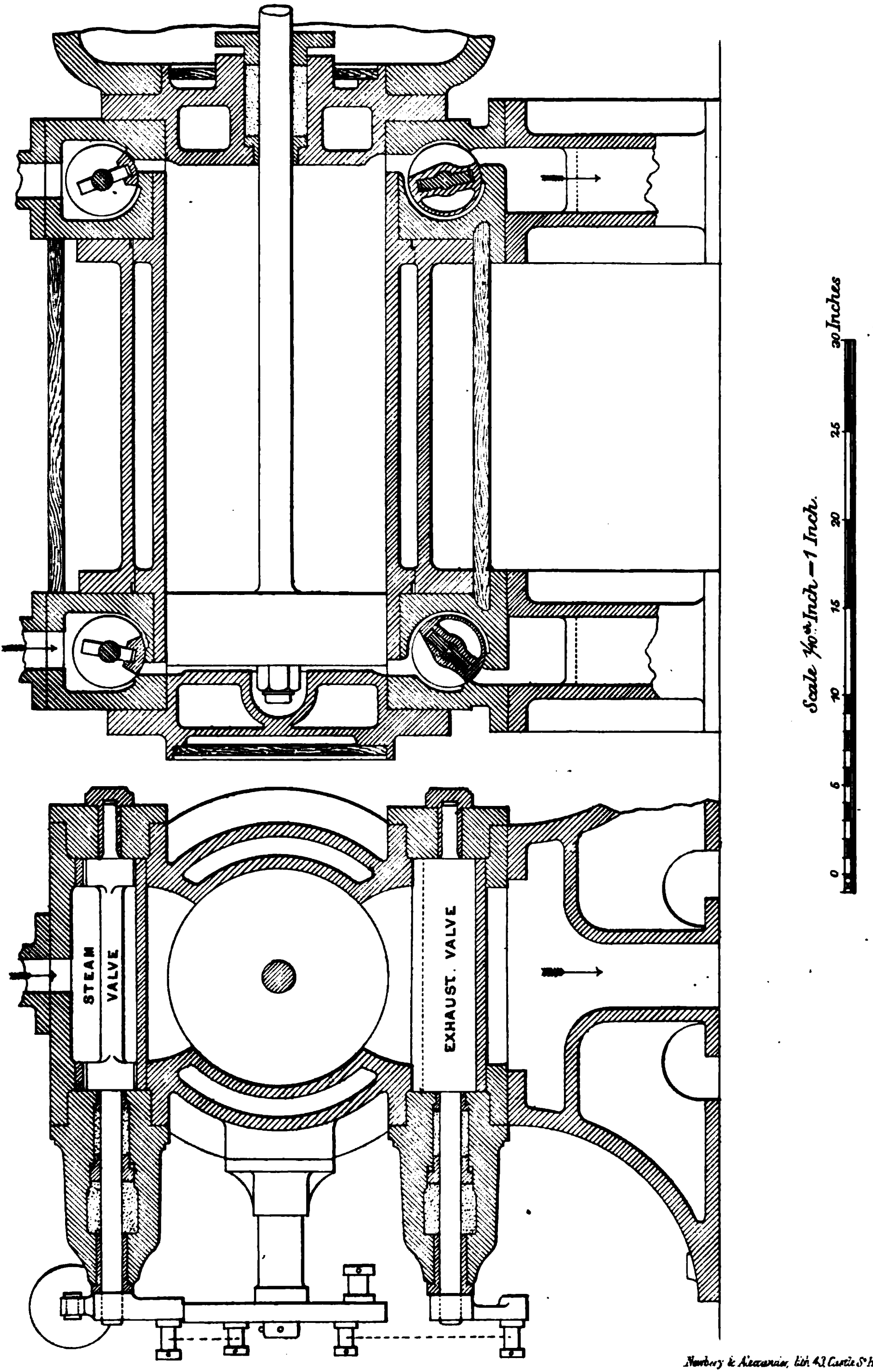


WATTS ORIGINAL LIBERATING VALVE GEAR.

N.P. Burgh, Dir.

E. & F. N. Spon, 48, Charing Cross, London

SECTIONAL ELEVATION OF THE CORLISS-VALVES, GEAR, AND CYLINDER OF THE HORIZONTAL ENGINE AT THE WOOLWICH ARSENAL.



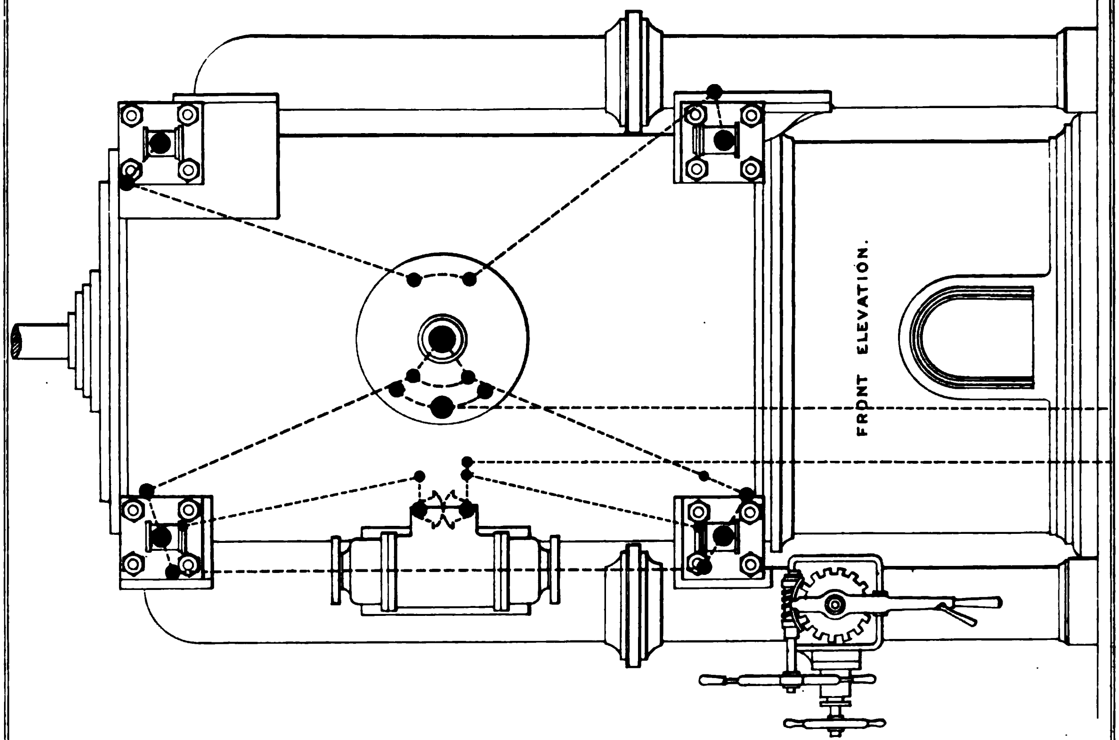
N.P. Burgh, Direx.

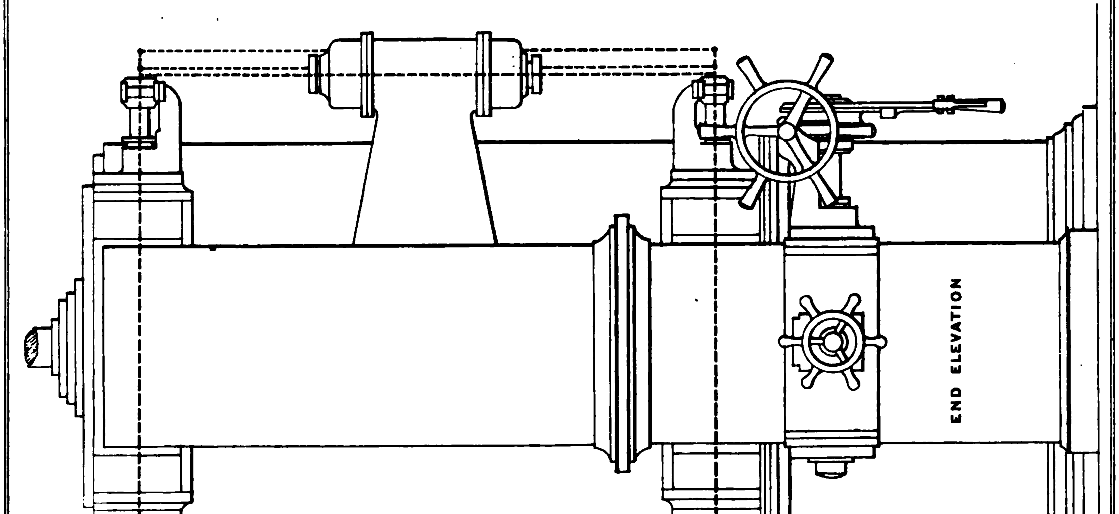
Newbury & Alexander, Lith. 43 Castle St. Holborn

E & F N Spon 48, Charing Cross, London

ELEVATION OF "CORLISS" VALVE GEAR, AND CYLINDER OF THE BEAM ENGINE ERECTED AT SALTAIRE.

BY MESS^RS HICK, HARGREAVES & C^O





Scale 1/30th Inch – 1 Inch.

0 1 2 3 4 5 6 7 8 Feet

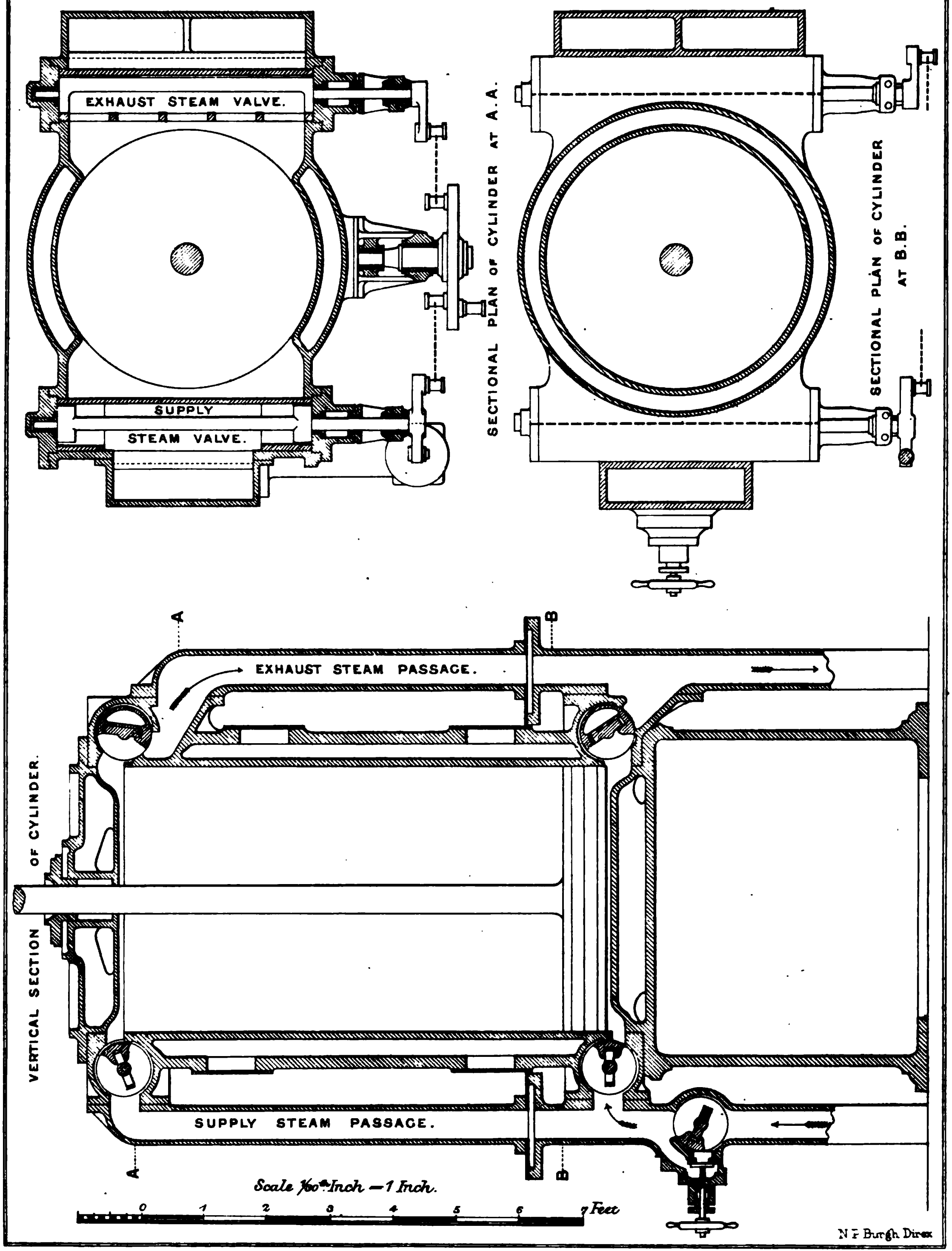
N P Burgh Direx

Newbery & Alexander lith 47 Castle St Holborn

E & F N Spon, 48, Charing Cross, London.

Plate 43.

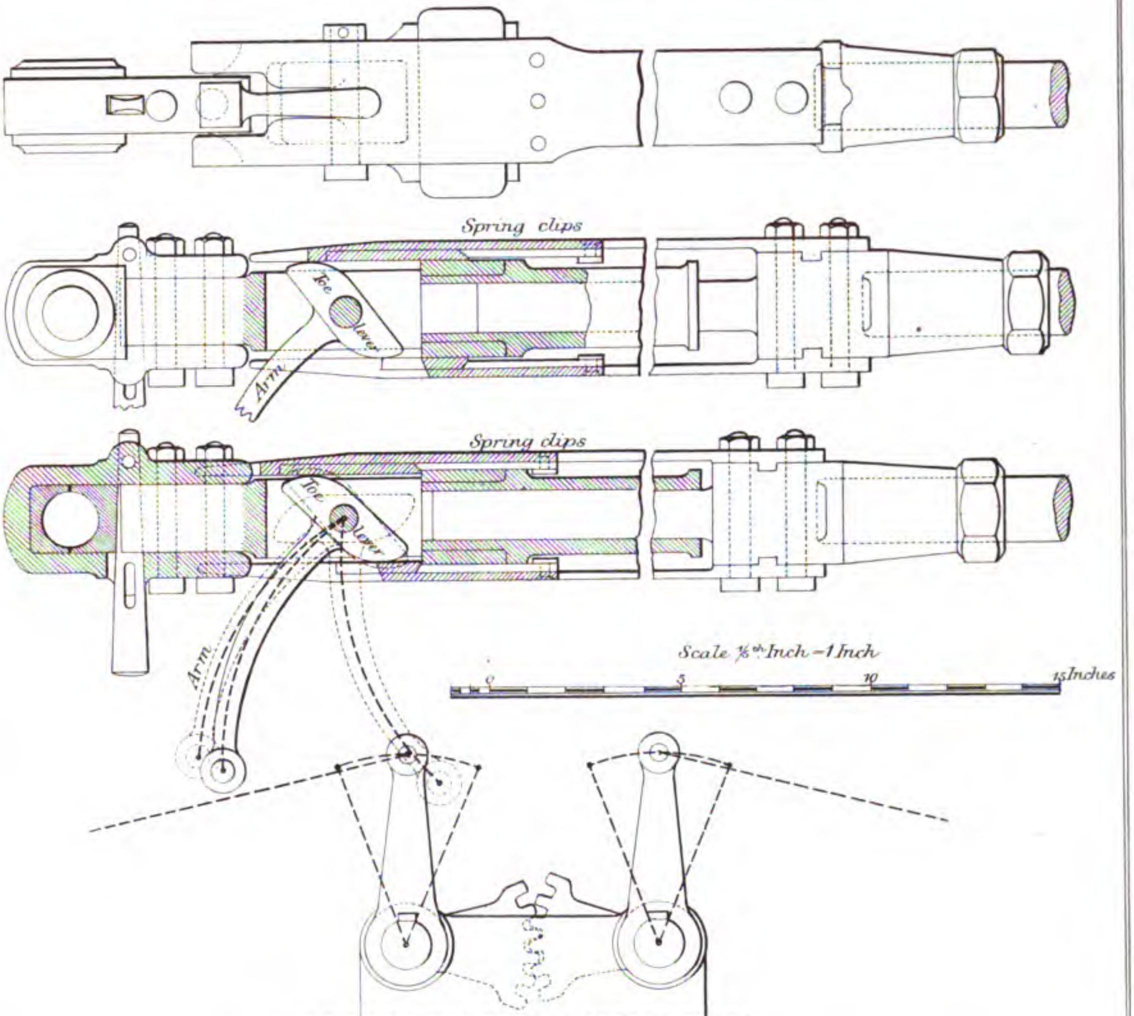
SECTIONS OF THE CYLINDER & VALVES ERECTED AT SALTAIRE.


EXHAUST STEAM VALVE.
SUPPLY
STEAM VALVE.
SECTIONAL PLAN OF CYLINDER AT A.A.
SECTIONAL PLAN OF CYLINDER AT B.B.
A
B
EXHAUST STEAM PASSAGE.
VERTICAL SECTION OF CYLINDER.
SUPPLY STEAM PASSAGE.
A
B
Scale 1/60th Inch — 1 Inch.
0
1
2
3
4
5
6
7 Feet

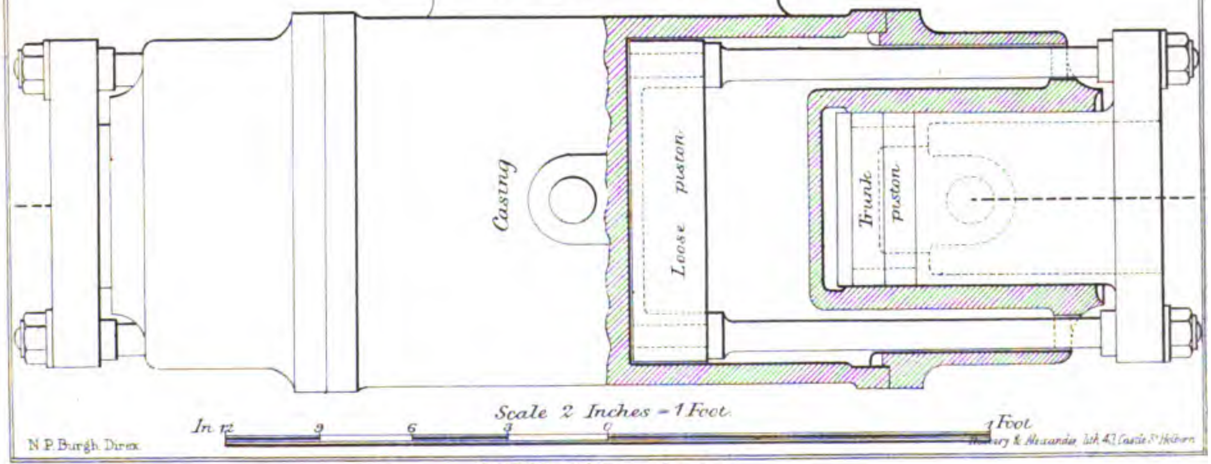
N. F. Burgh Direx

E. & F. N. Spon 48, Charing Cross, London

LIBERATING GEAR FOR "CORLISS" VALVES. BY MESSRS SPENCER & INGLIS.



AIR-SPRING-DASH POT OF THE SALTAIRE ENGINE.

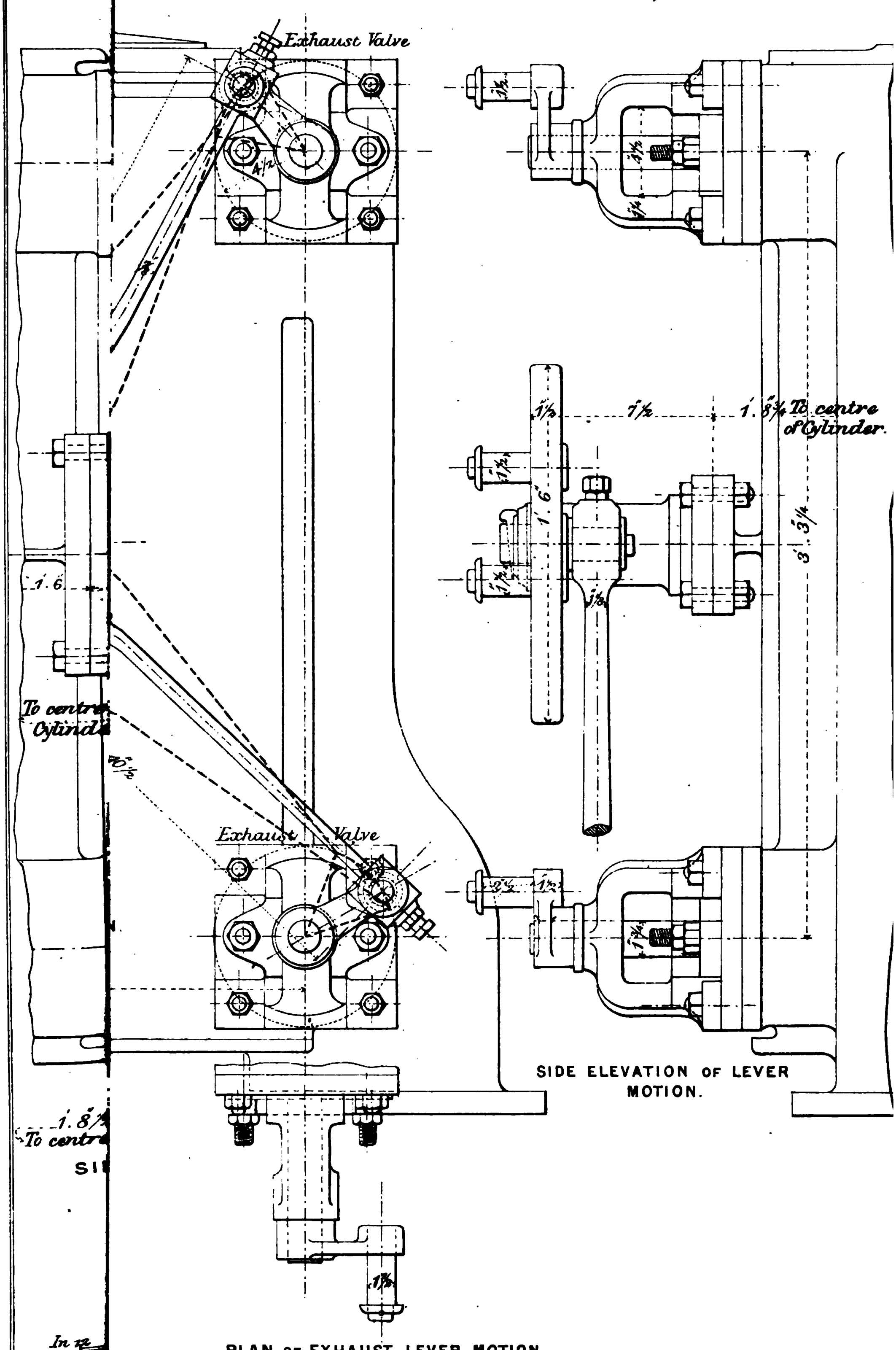


N. P. Burgh. Direx.

ry & Alexander, lith 43 Castle St Holborn

E & F N Spon, 48, Charing Cross, London.

S.S. 100 HP. NOML. COLLY. BY J.F. SPENCER, ENGINEER.



SIDE ELEVATION OF LEVER MOTION.

PLAN OF EXHAUST LEVER MOTION.

Newbury & Alexander, lith. 43

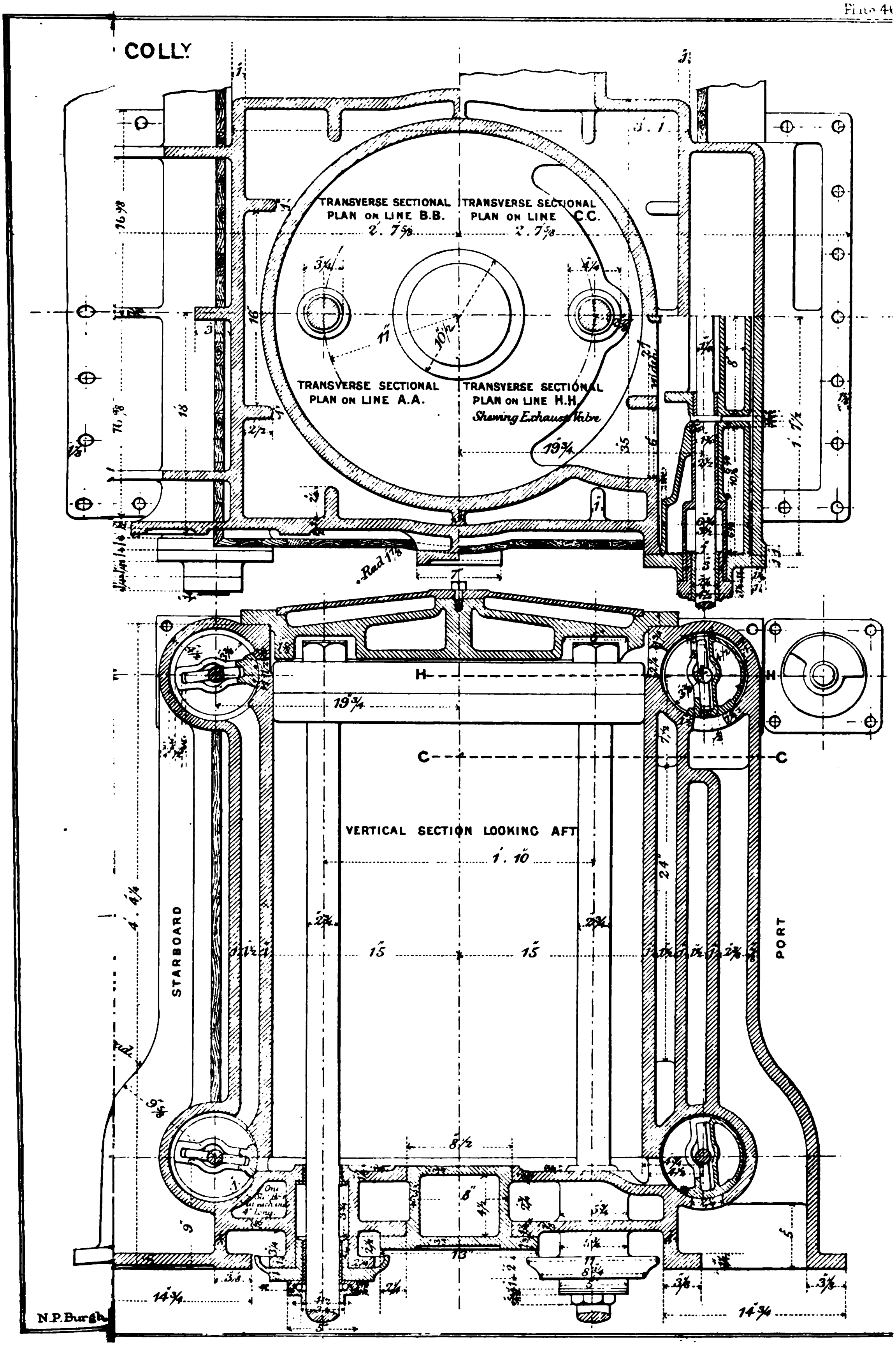
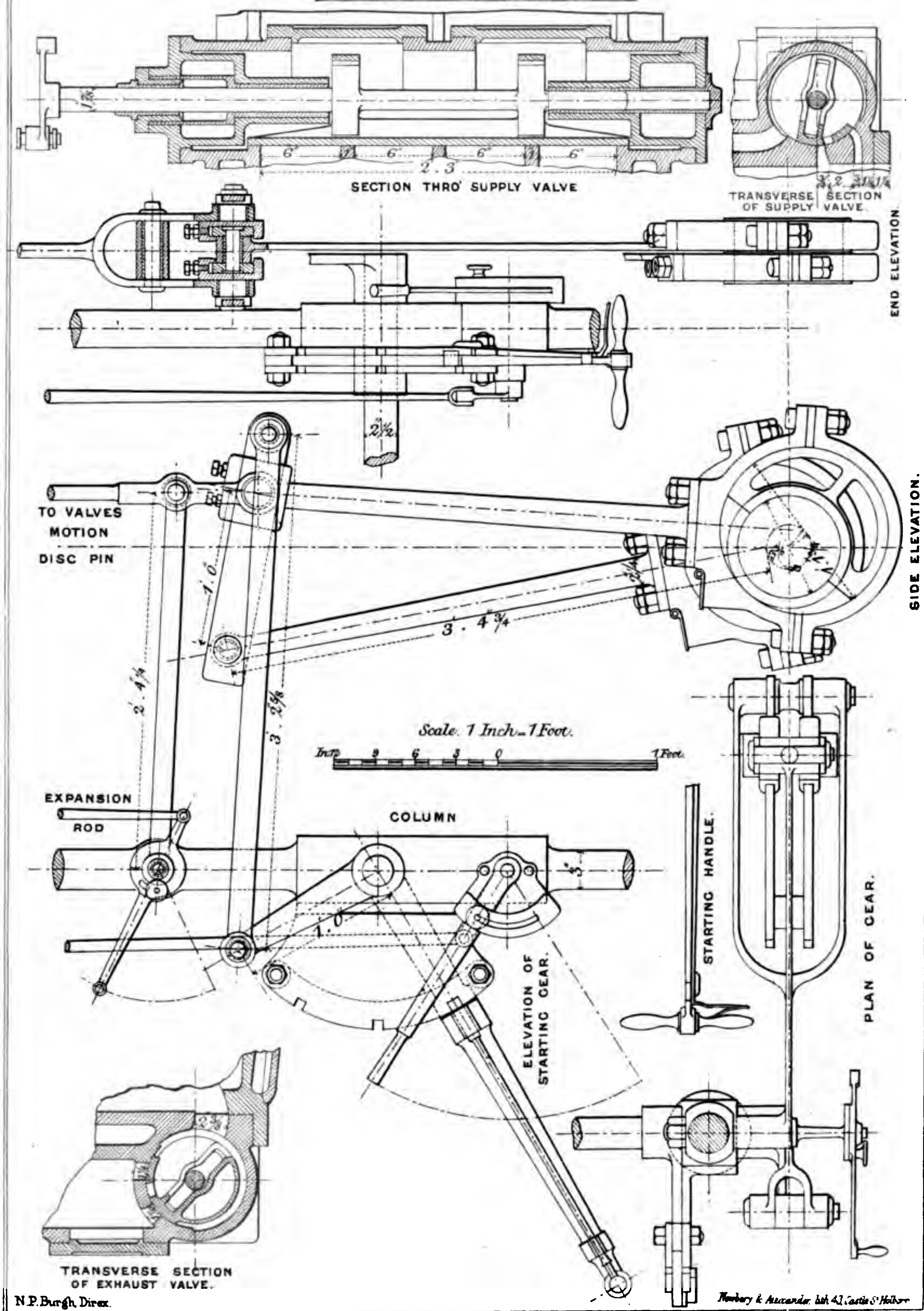

COLLY.
TRANSVERSE SECTIONAL PLAN ON LINE B.B.
TRANSVERSE SECTIONAL PLAN ON LINE C.C.
TRANSVERSE SECTIONAL PLAN ON LINE A.A.
TRANSVERSE SECTIONAL PLAN ON LINE H.H.
Shewing Exhaust Valve
2′. 7⅝
2′. 7⅞
10½
11
19¾
Rad 1⅛
H
H
C
C
19¾
VERTICAL SECTION LOOKING AFT
1′. 10
15
15
2¾
2¾
24
STARBOARD
PORT
4′. 4¼
8½
8
14¾
14¾
3⅛
3⅛
N.P.Burgh

Plate 47.

LINK-MOTION, STARTING-GEAR & DOUBLE PORTED "CORLISS" VALVES. FOR THE MARINE ENGINES 100.H.P. NOML. COLLY

BY J. F. SPENCER, ENGINEER.

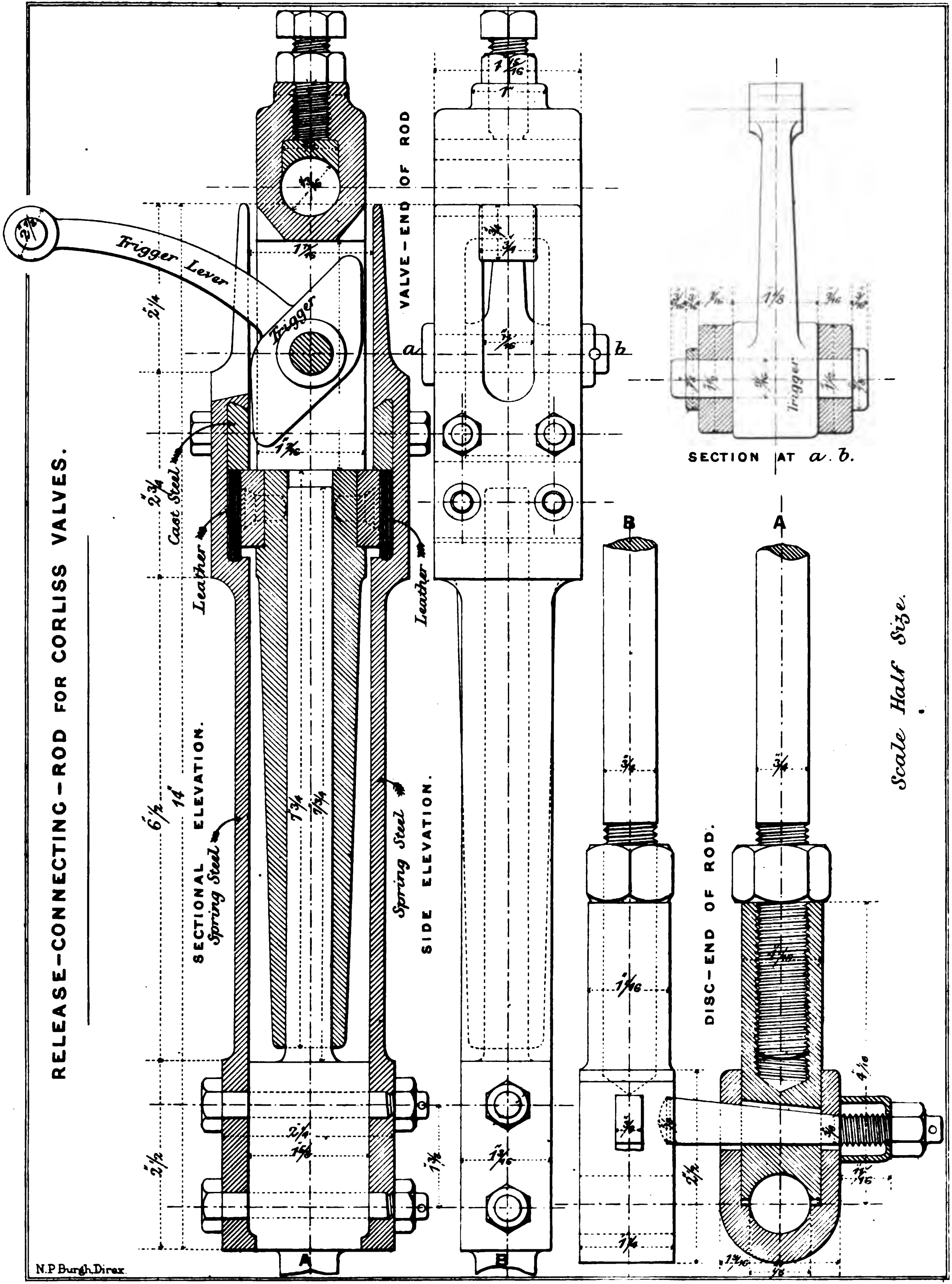


N.P. Burgh, Direx.

Newbery & Alexander, lith 41 Castle St Holborn

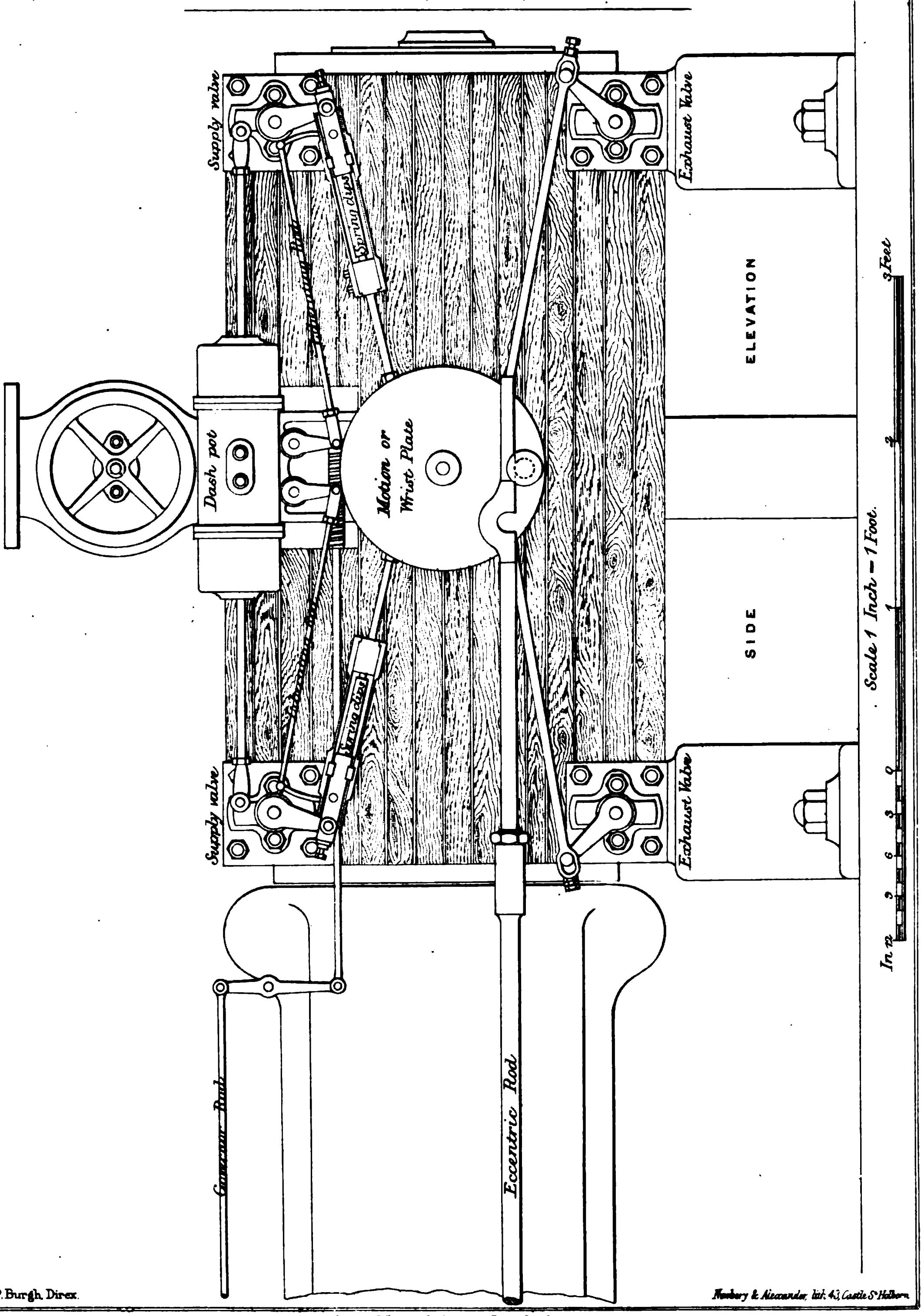
E & F N Spon, 48, Charing Cross, London

RELEASE-CONNECTING-ROD FOR CORLISS VALVES.



E & F. N. Spon, 48, Charing Cross, London

ARRANGEMENT OF "CORLISS" VALVE GEAR FOR A HORIZONTAL ENGINE.
CYLINDER 18 INS. DIAMETER. STROKE OF PISTON 4 FEET.
BY M^R R. DOUGLAS, ENGINEER, KIRKCALDY.

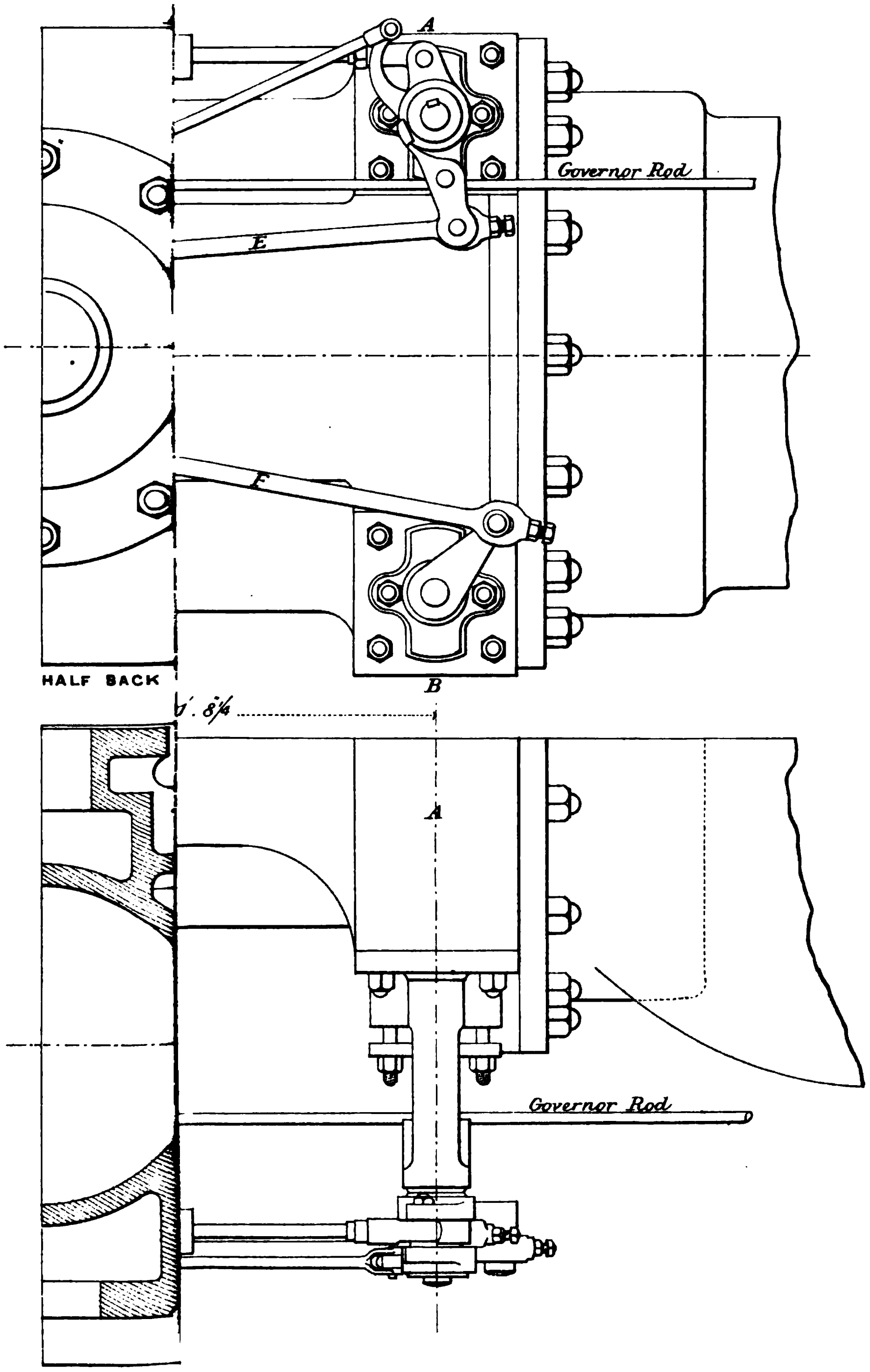


N. P. Burgh, Direx.

Newbury & Alexander, lith. 43, Castle S^t Holborn.

E. & F. N. Spon, 48, Charing Cross, London.

AS, DUNNIKIER FOUNDRY, KIRKCALDY, N.B.

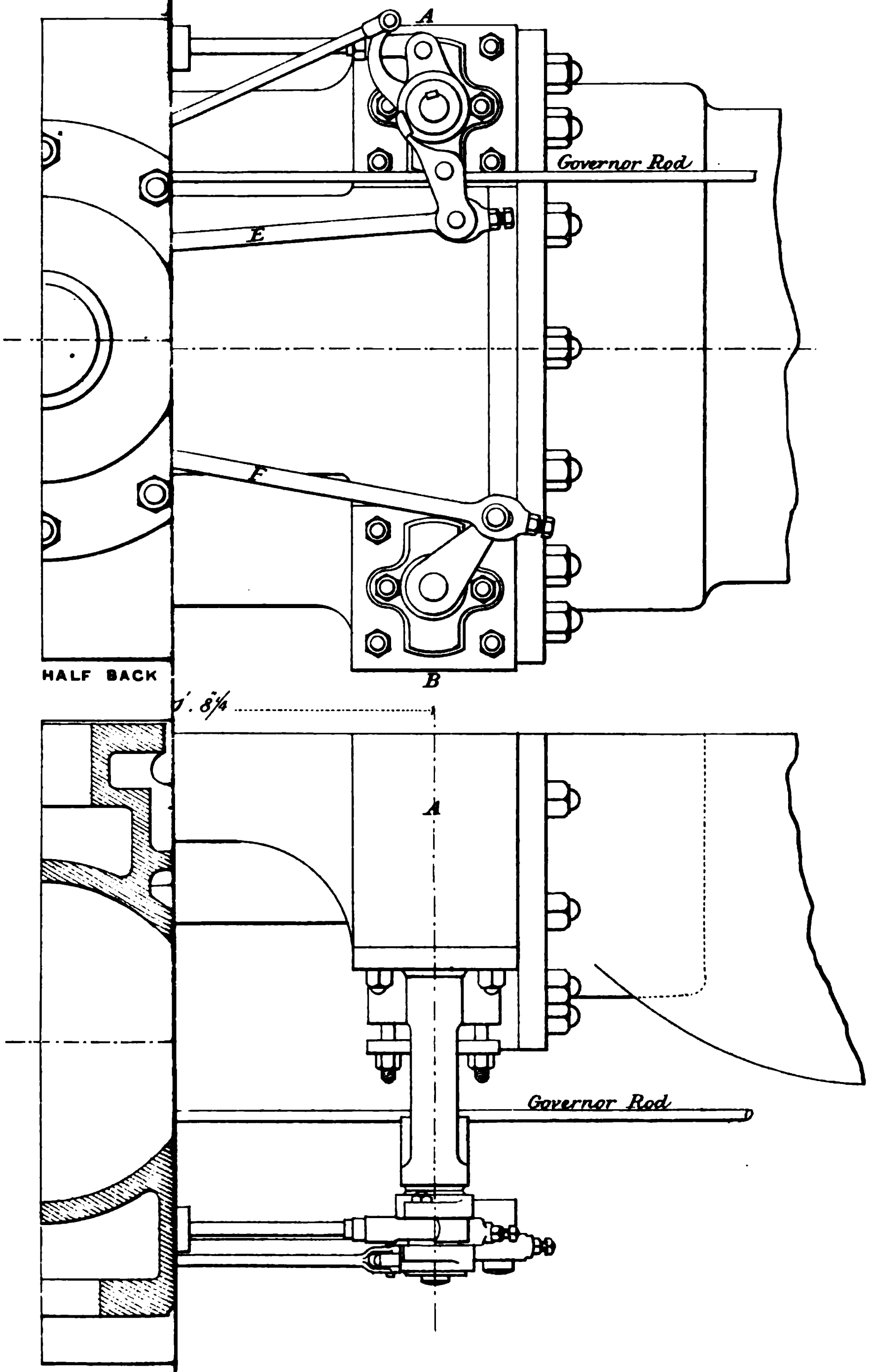


HALF CR

N P Burgh. Direx

Newbery & Alexander, Lith. 43 Castle St Holborn

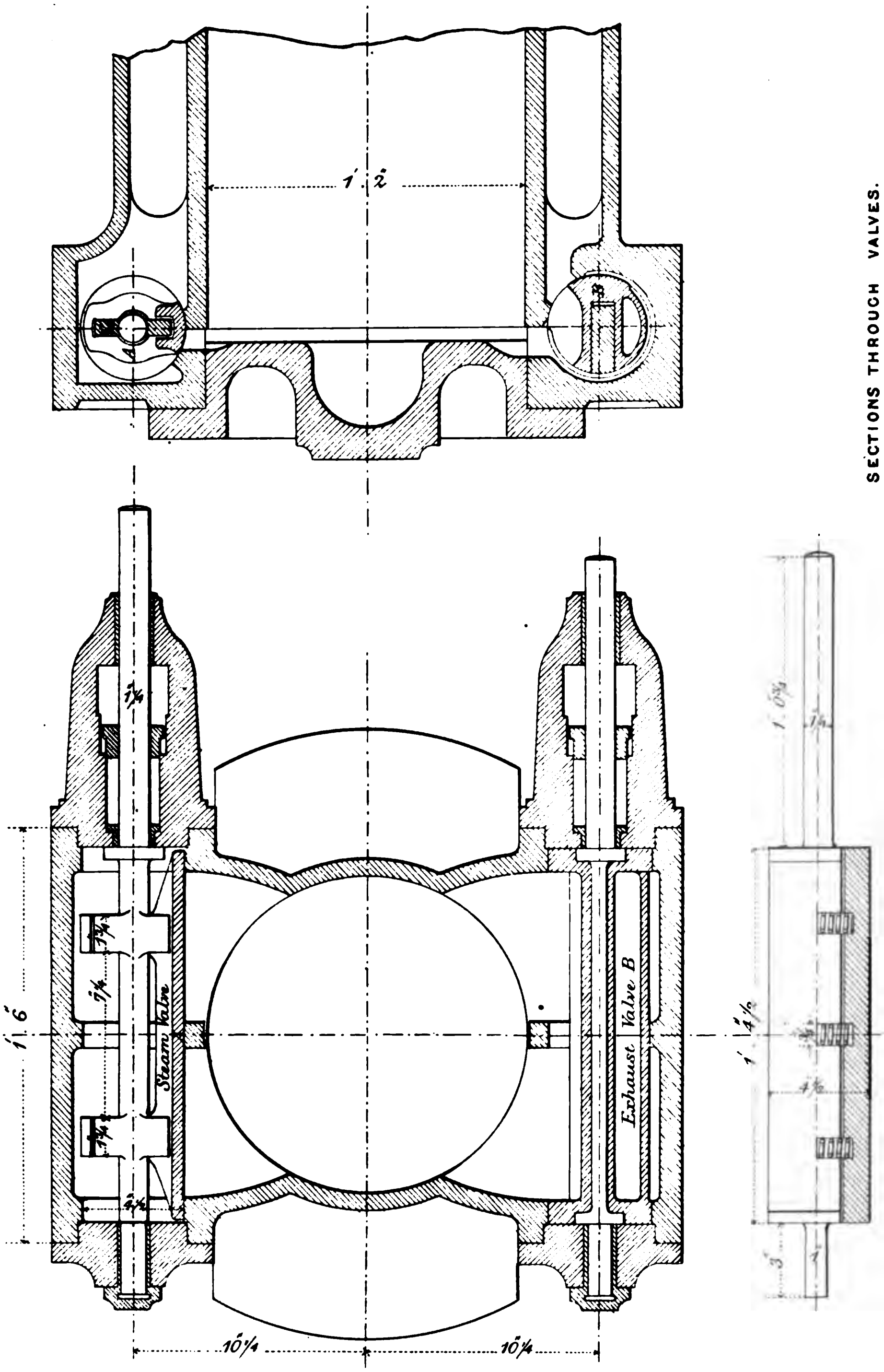
AS, DUNNIKIER FOUNDRY, KIRKCALDY, N.B.



N P Burgh Direx

Newbery & Alexander, lith 43 Castle St Holborn

SECTIONAL ELEVATION OF CORLISS VALVES & CHAMBERS



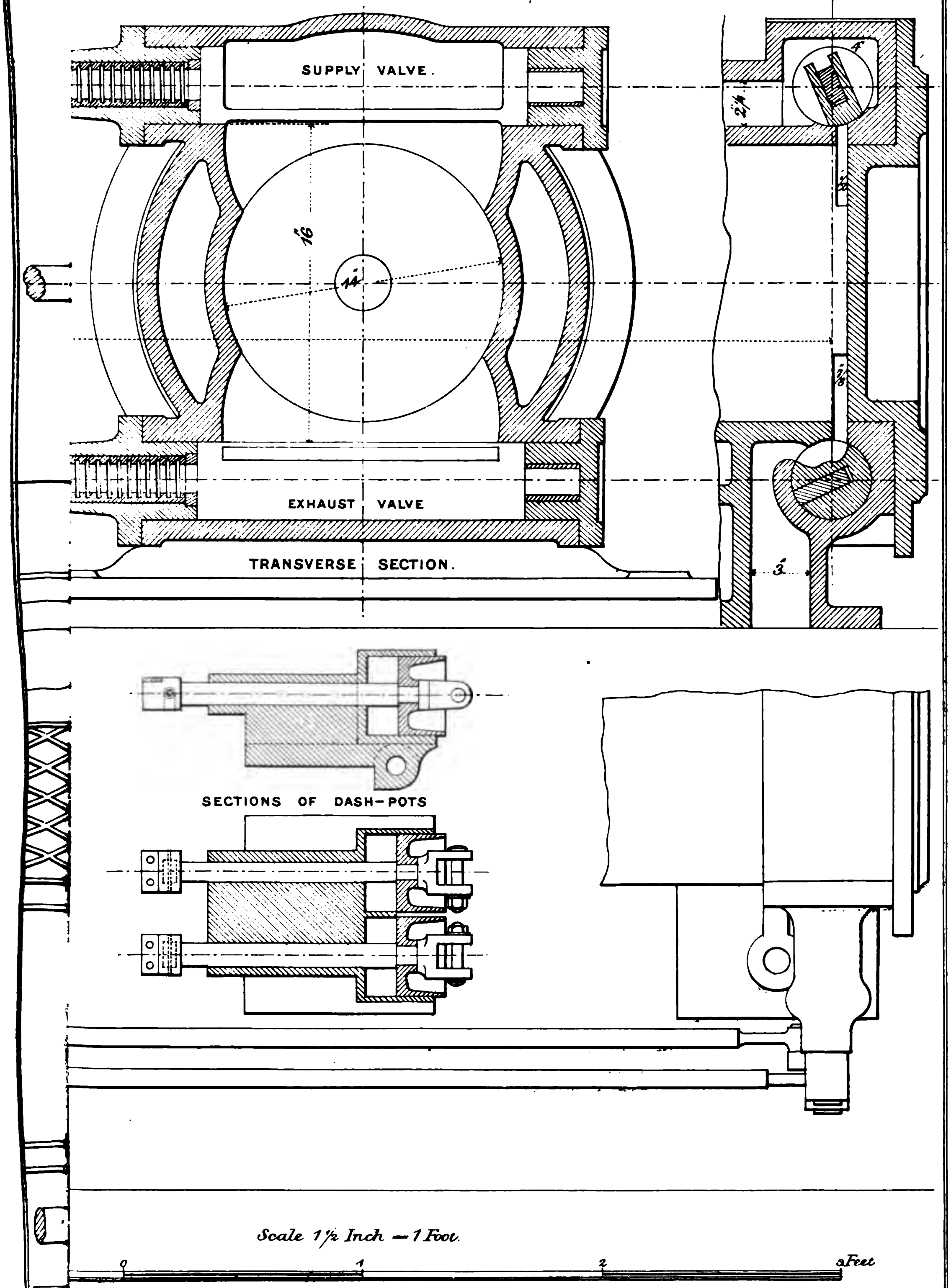
Scale 1 1/2 Inch = Foot

N P Burgh Direx.

Newbar & Alexander lith 43 Castle St Holborn

E & F N Spon 48 Charing Cross London

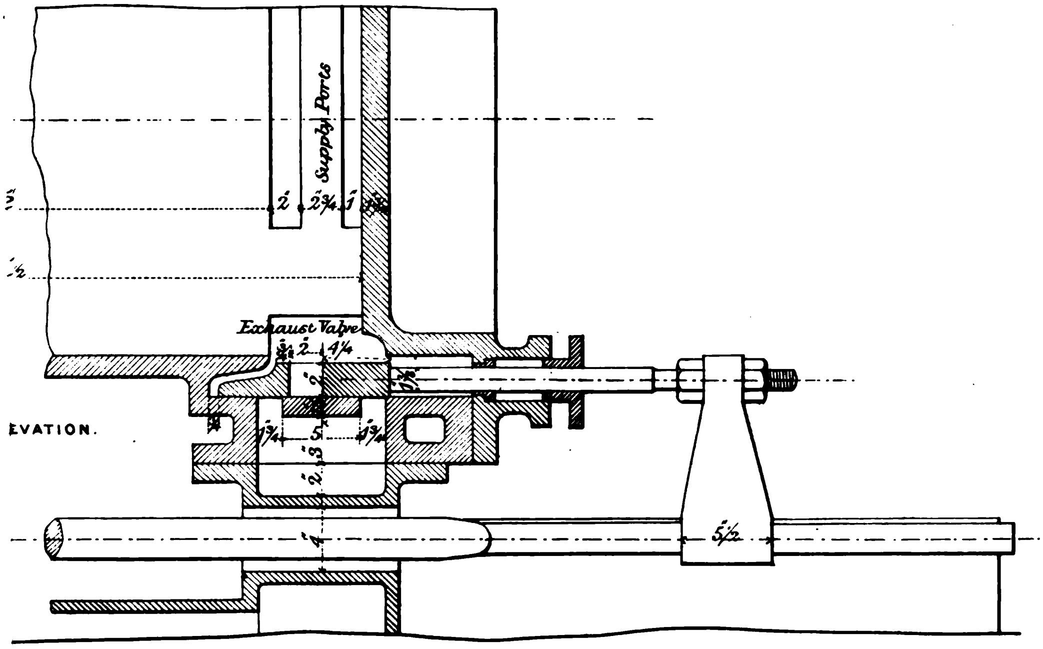
CT ACTING ENGINE. BY MESSRS J & E. WOOD.



Scale 1½ Inch — 1 Foot.

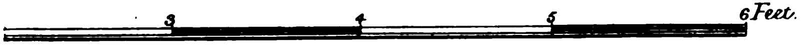
Newbery & Alexander lith 43 Castle St Holborn

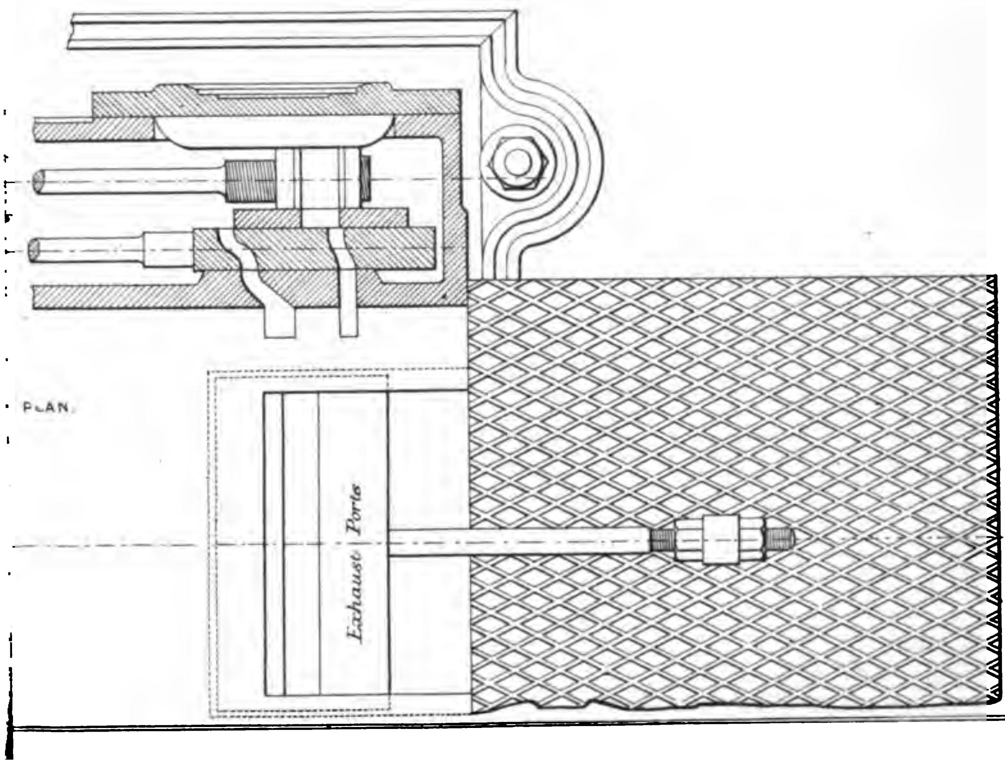
N OF THE STEAM & GOVERNOR GEAR TO REGULATE THE CUT-OFF.



EVATION.

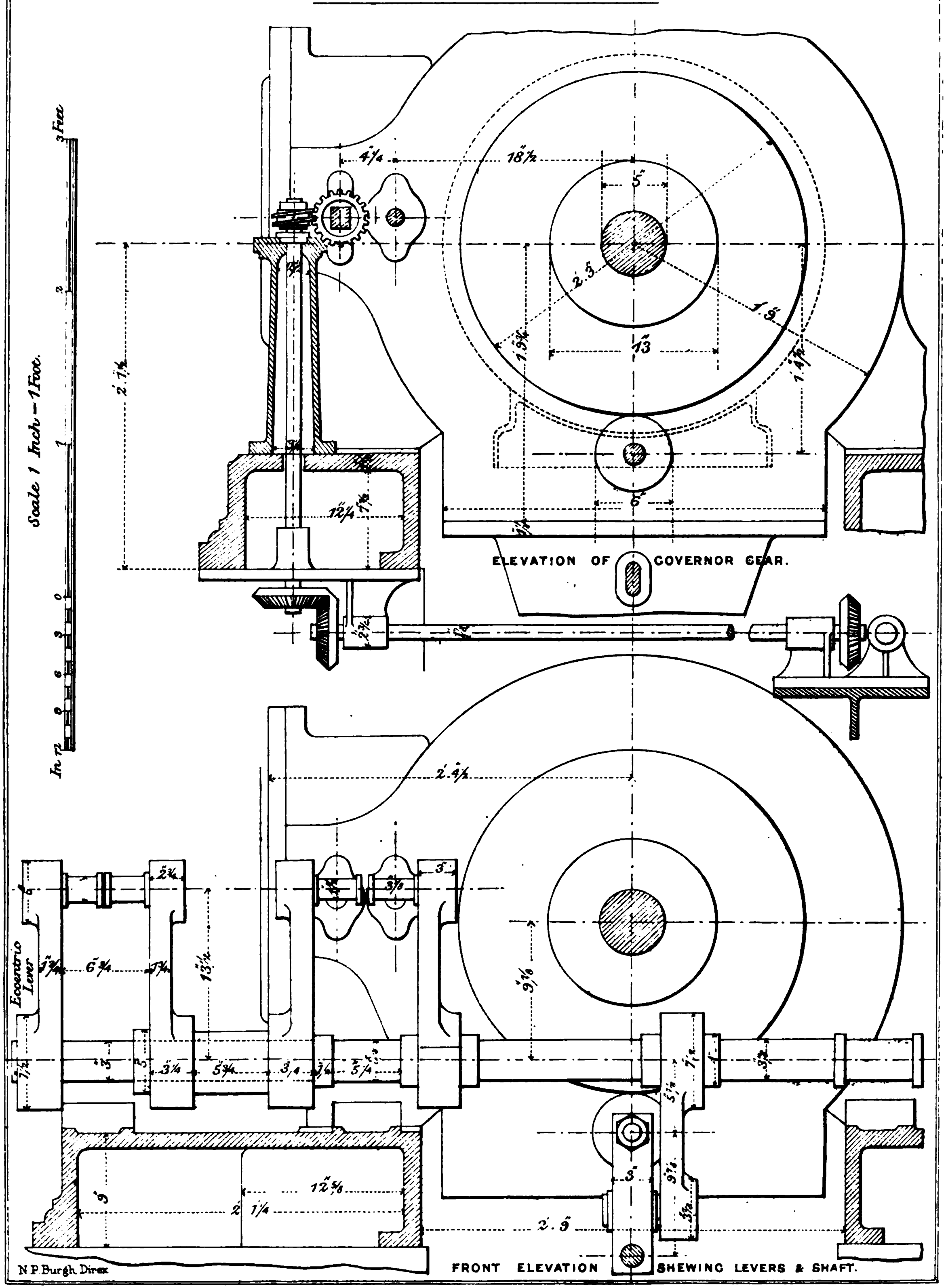
1 Inch — 1 Foot.





PLAN.

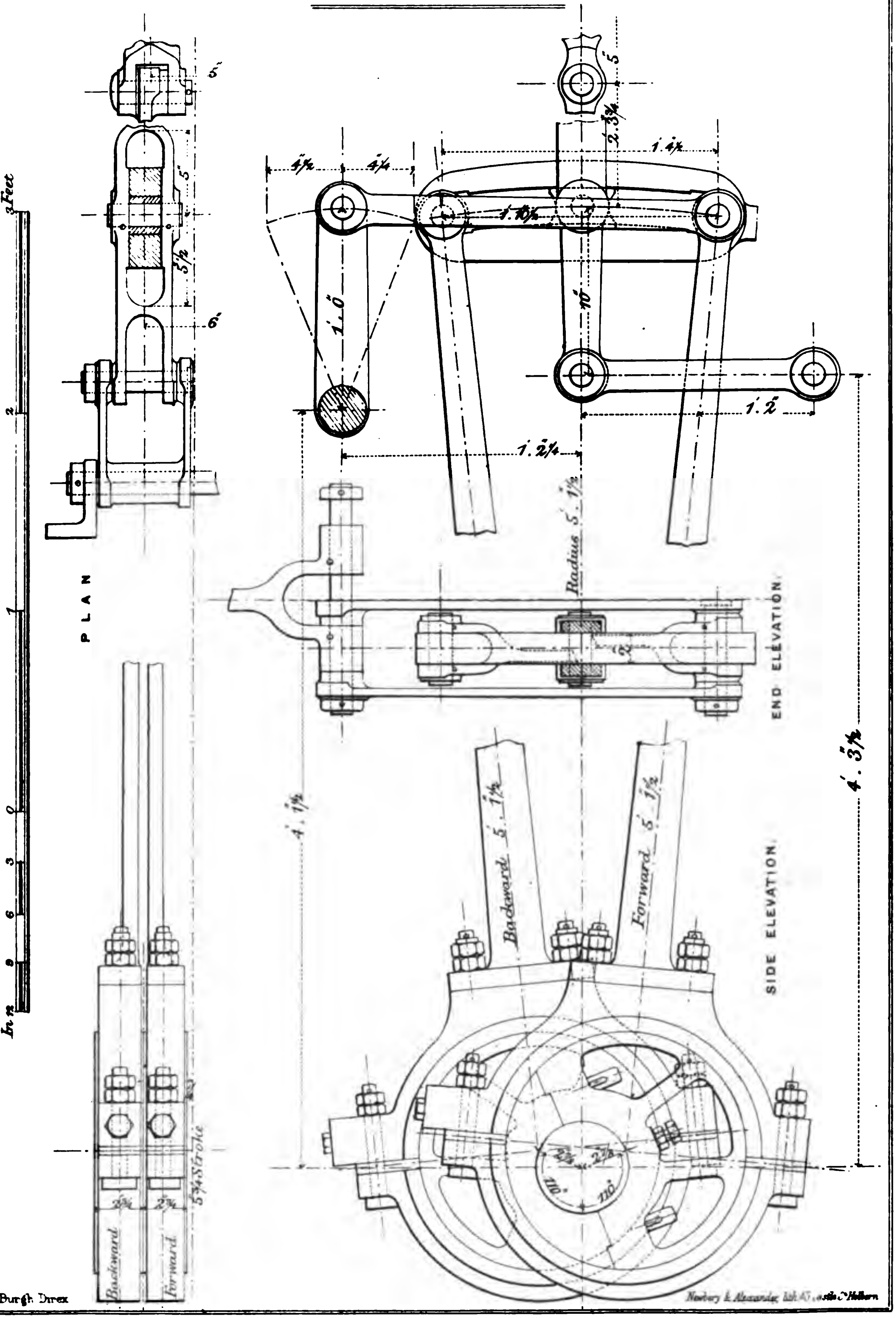
ELEVATIONS OF THE ENGINE SHOWN BY PLATE 53. BY MESSRS J & E. WOOD.



E. & F. N. Spon, 48 Charing Cross, London

ARRANGEMENT OF LINK MOTION FOR A LOCOMOTIVE.

CONSTRCTED BY MESSRS SHARP, STEWART & CO LIMITED, 1867.

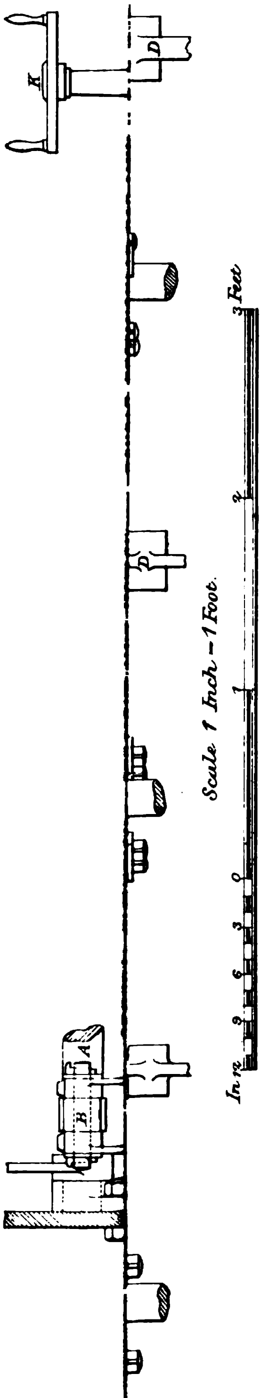


N P Burgh Direx

Newbery & Alexander, lith 63, Castle St Holborn

E & F N Spon, 48, Charing Cross, London

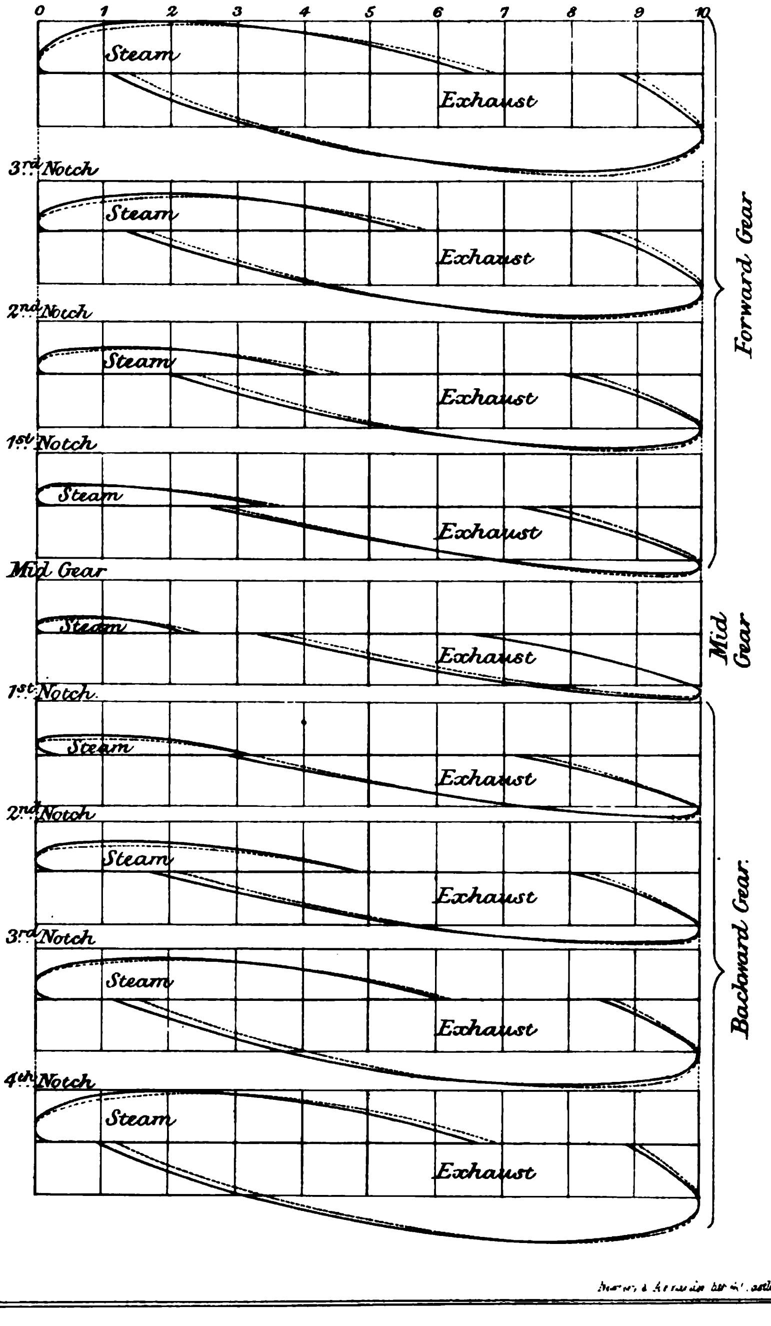
N AS APPLIED TO LOCOMOTIVE ENGINES.



DIAGRAMS SHEWING DISTRIBUTION OF STEAM.

Lap of Valve 1¼ Inch. Width of Steam Port 1⅜ Inch.

Throw of Eccentrics 5 Inches.



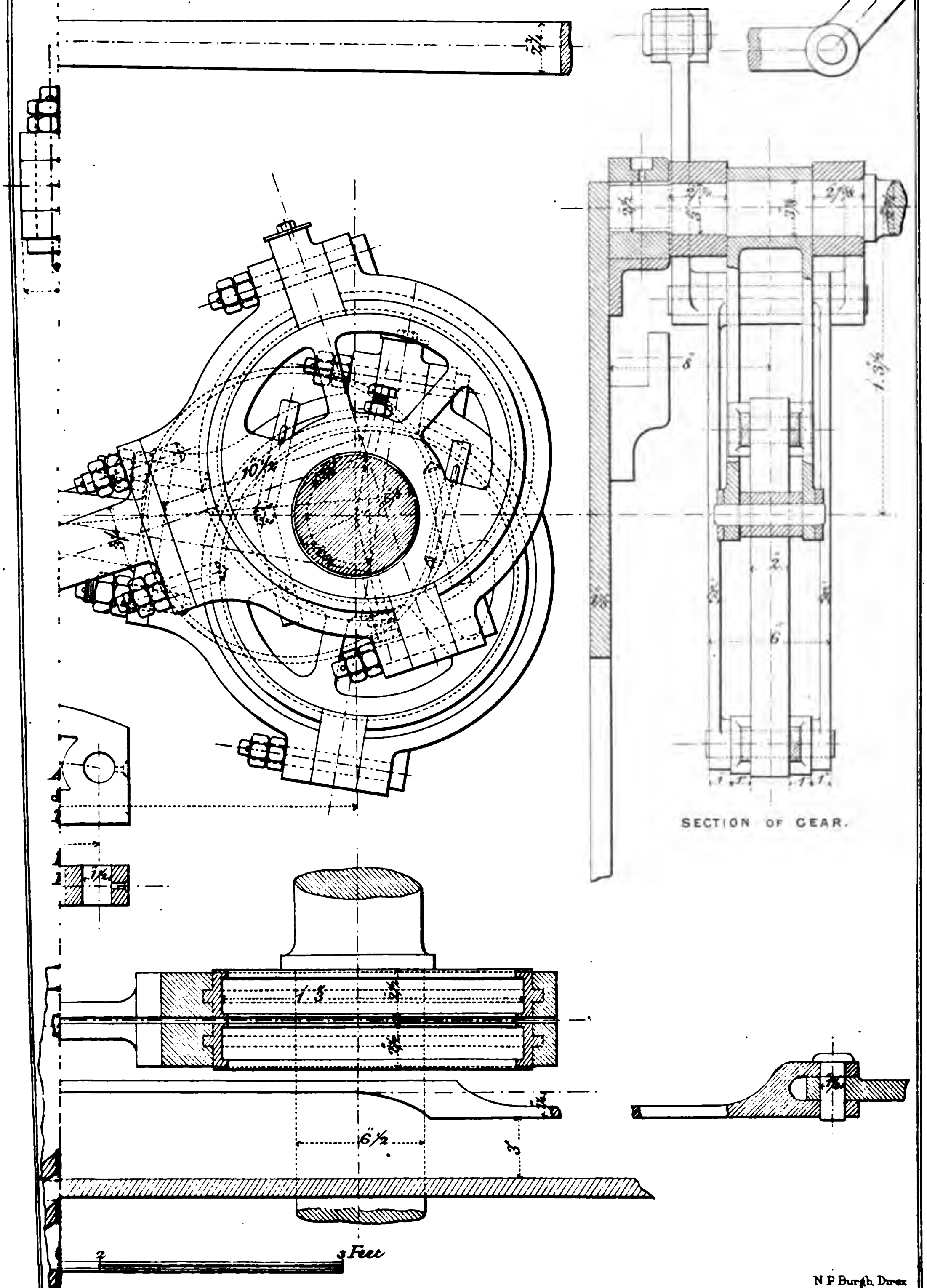
N.P. Burgh. Direx

[illegible] Castle St Holborn

Plate 60.

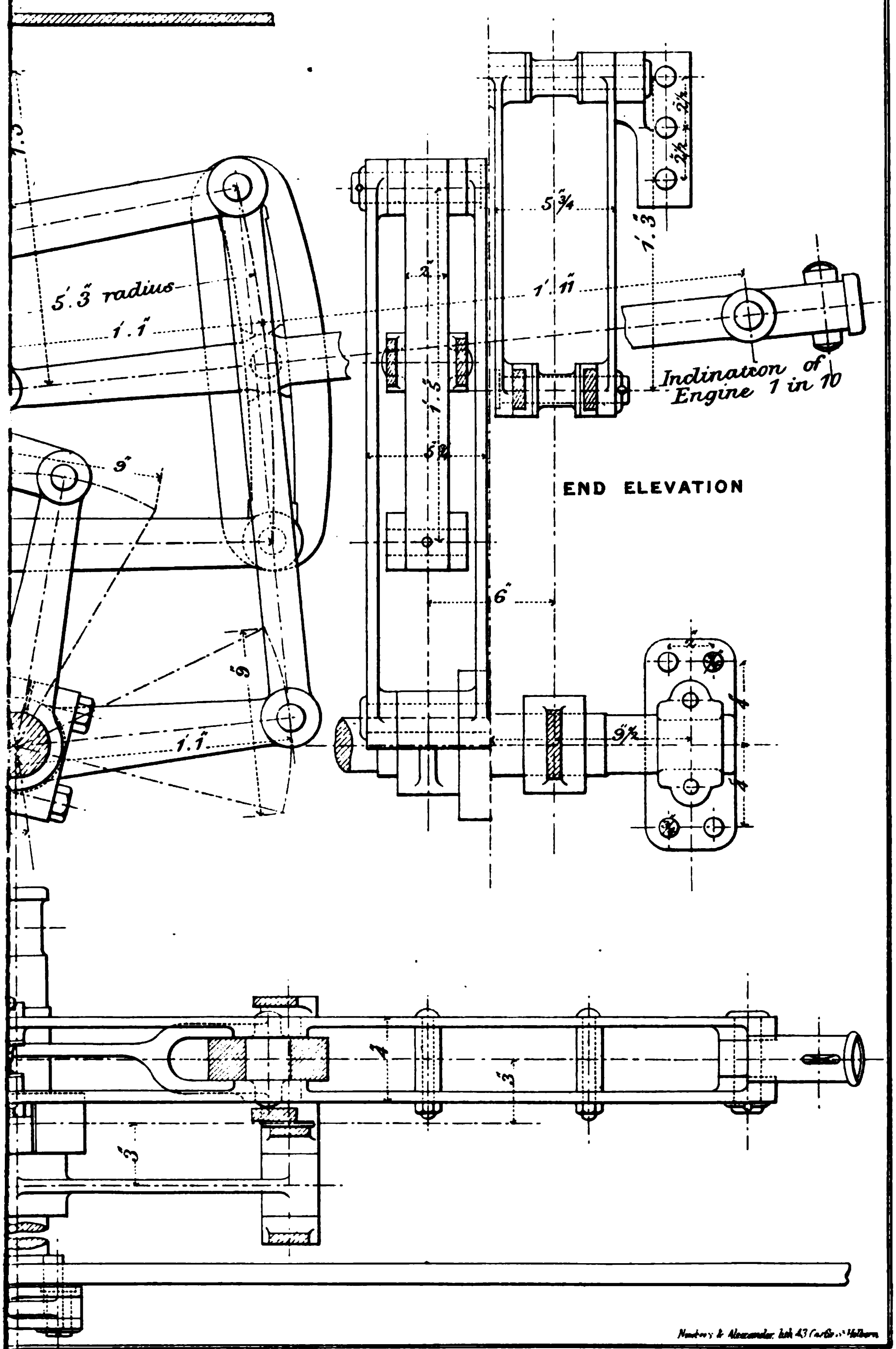
ION &c. OF A PASSENGER LOCOMOTIVE.

JANY 1868. FOR THE G.I.P.R. — G. BERKLEY, ESQ. ENGINEER.



N P Burgh Direx

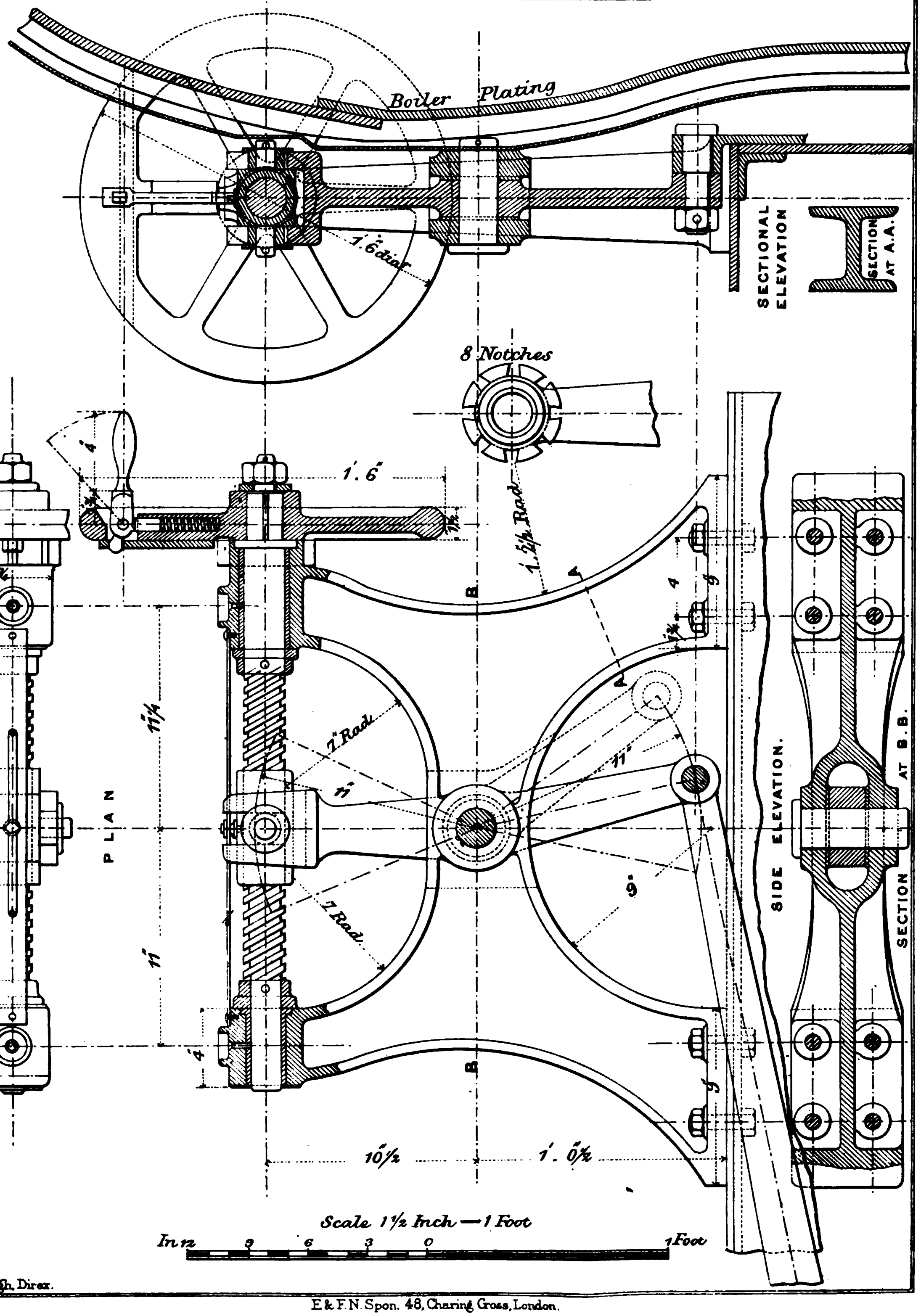
UBS & Cº OF GLASGOW, JANY 1868. FOR THE G.I.P.R.



Newbery & Alexander, lith 43 Castle St. Holborn

REVERSING GEAR FOR GOODS ENGINE FOR THE G.I.P.R.

C. BERKLEY, ESQ. ENGINEER.

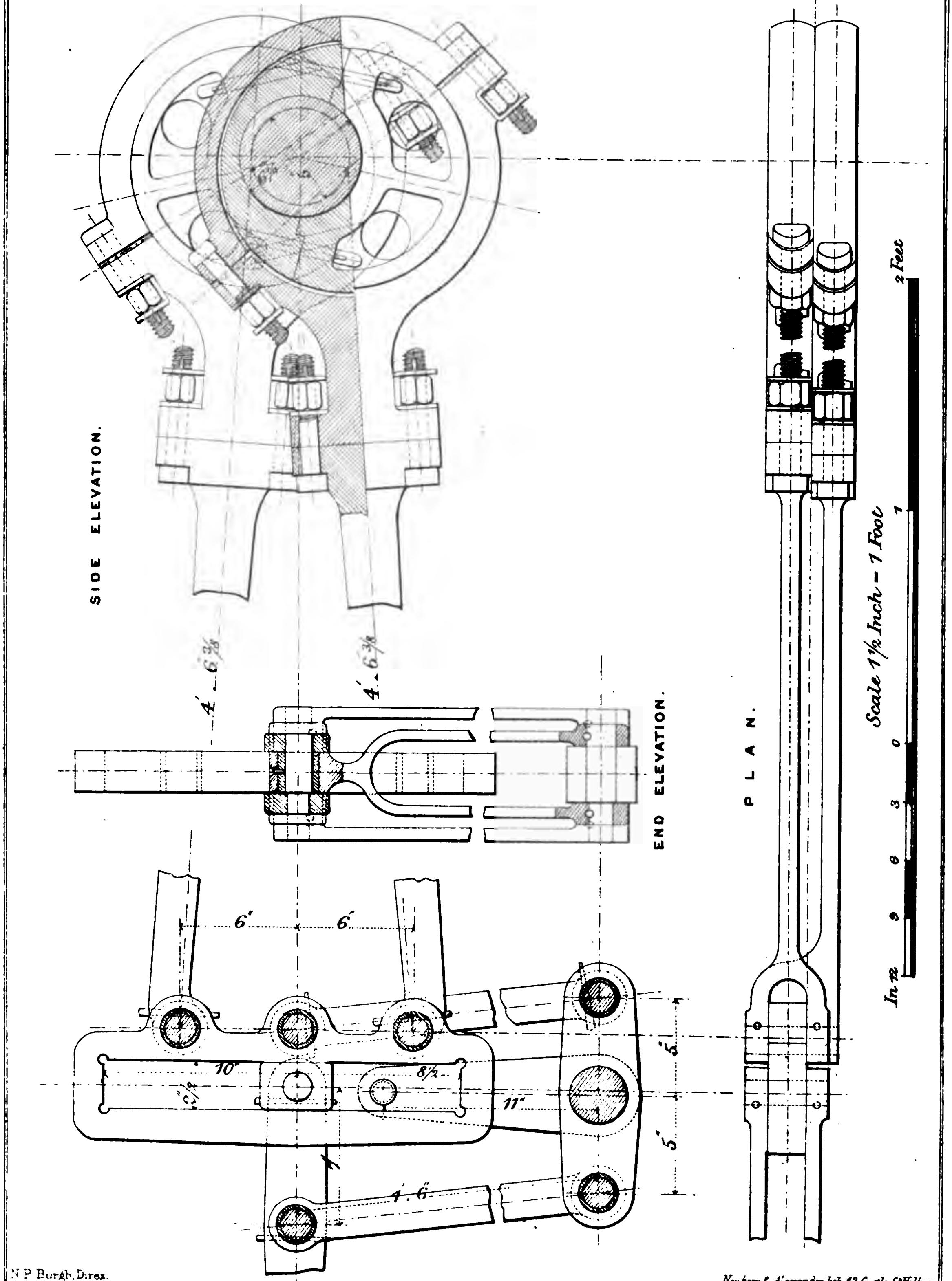


N.P. Burgh, Direx.

E & F.N. Spon. 48, Charing Cross, London.

Plate 62.

ALLAN'S LINK MOTION AS CONSTRUCTED BY C.H.BEATTIE, ESQ. L & S.W.R. 1870.

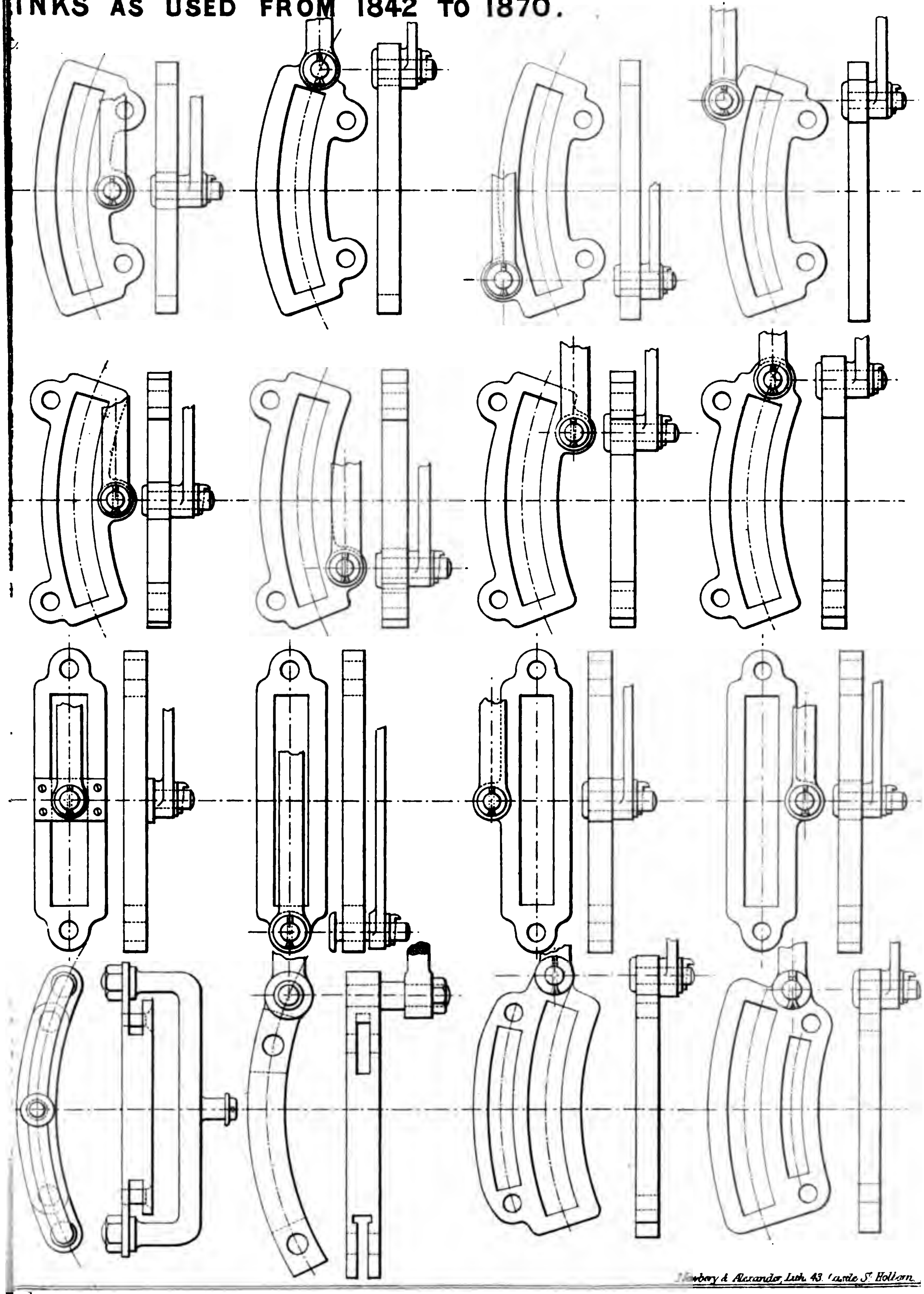


N P Burgh, Direx.

Newbery & Alexander lith 43 Castle St Holborn

E & F N Spon 48, Charing Cross London.

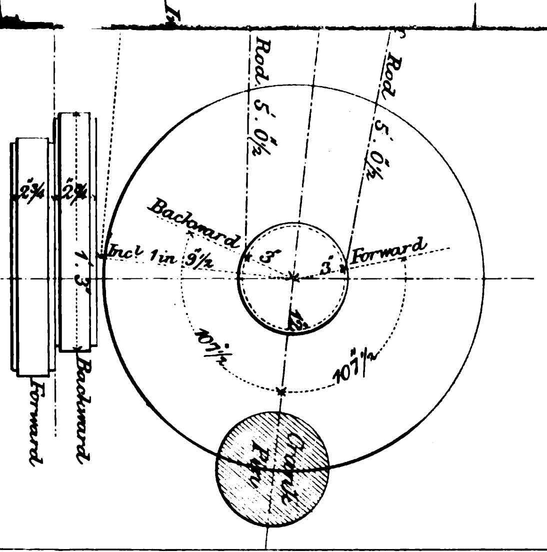
INKS AS USED FROM 1842 TO 1870.

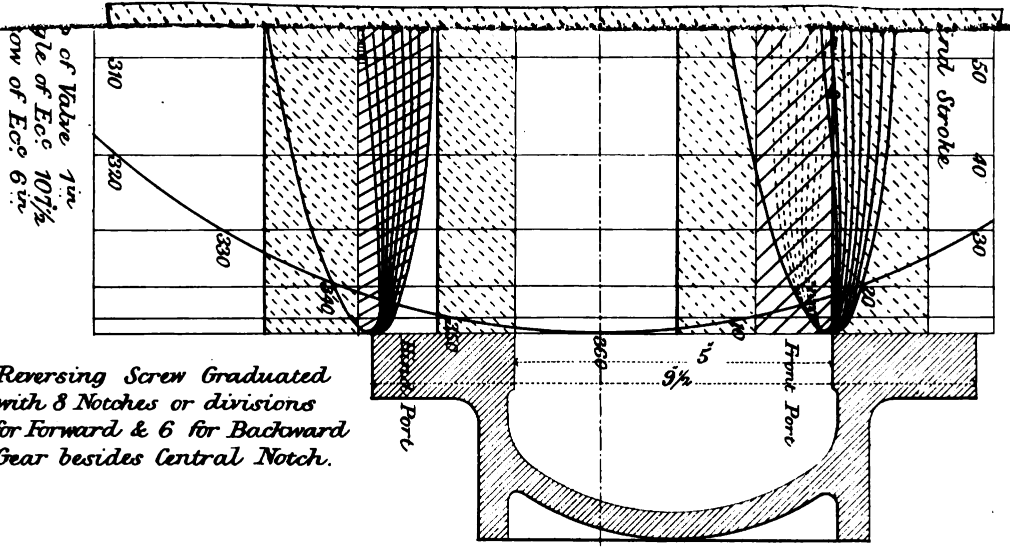


Newbury & Alexander Lith. 43 Castle St Holborn.

ndon.

E FOR THE C.I.P.R. C. BERKELY, ESQ. ENGINEER.





Reversing Screw Graduated with 8 Notches or divisions for Forward & 6 for Backward Gear besides Central Notch.

Table of the distribution of Steam reckoned in per centages of the Stroke of Piston in Cylinder for the front & back Strokes Respectively & in forward & backward Gear of the Link Motion

FORWARD GEAR.

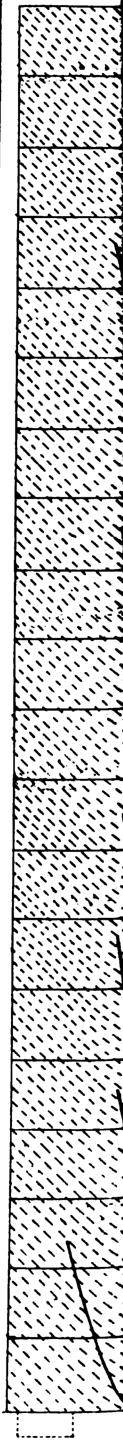
	Front Stroke								Back Stroke						
	Effective pressure					Back pressure (on opposite side of Piston)			Effective Pressure				Back pressure (on opposite side of Piston)		
Notch	Travel	Lead	Full port	Admission	Expansion	Exhaust	Compression of Exhaust	Compression of Counter admission	Lead	Full port	Admission	Expansion	Exhaust	Compession of Exhaust	Compression of Counter-admission
1	4⅞ in	3/16 in	15/16 in	71·5	20	8·5	8·5	0	3/16 in	1 3/16 in	70·5	19·5	9·5	9·5	·5
2	3 15/16	3/16	13/16	66	23·5	11	11	·5	3/16	1	65	22	12·5	12·5	·5
3	3 9/16	3/16 f	7/16	59	28	12·5	12·5	·5	3/16 f	13/16 f	59	26	14	14	1
4	3 5/16	¼ b	9/16 f	51	32	16·5	16·5	·5	¼ b	11/16	52	29	18	18	1
5	3 1/16	¼	½	43	35	21	21	1	¼	9/16	44·5	32·5	21·5	21·5	1·5
6	2⅞	¼ f	7/16	35	37	26	26	2	¼ f	7/16 f	36·5	35	26	26	2·5
7	2¾	5/16 b	⅜ f	27	38	31	31	4	5/16 b	⅜ f	27·5	38	30	30	4·5
8	2⅝	5/16	5/16 f	19·5	37·5	36·5	36·5	6·5	5/16	5/16 f	20	38	35	35	7

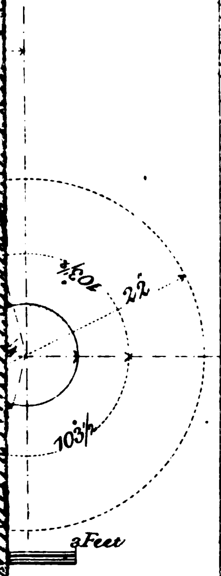
BACKWARD GEAR.

Notch	Travel	Lead	Full port	Admission	Expansion	Exhaust	Compression of Exhaust	Compression of Counter admission	Lead	Full port	Admission	Expansion	Exhaust	Compession of Exhaust	Compression of Counter-admission
1	3⅞	3/16 f	13/16	68·5	21	10	10	·5	3/16 b	1 1/16	70	18	11·5	11·5	·5
2	3½	¼	⅝ f	60	26	13·5	13·5	·5	3/16	13/16	63	22	14	14	1
3	3 3/16	5/16 b	½ f	51	31	17	17	1	¼ b	⅝ f	55	25	18	18	2
4	2⅞	5/16	7/16	40	36·5	21	21	2·5	¼	½	45·5	30	21·5	21·5	3
5	2 11/16	5/16	⅜ b	28·5	41	26·5	26·5	4	¼ f	⅜	34	35	25·5	25·5	5
6	2 9/16	5/16	5/16	17·5	42·5	32·5	32·5	7·5	¼ f	5/16	21	40	30	30	9

NOTE. In the Central notch the admission is 14 for the front & back Strokes in Forward Gear & 12 for the back & 10·5 for the front Stroke in Backward Gear.

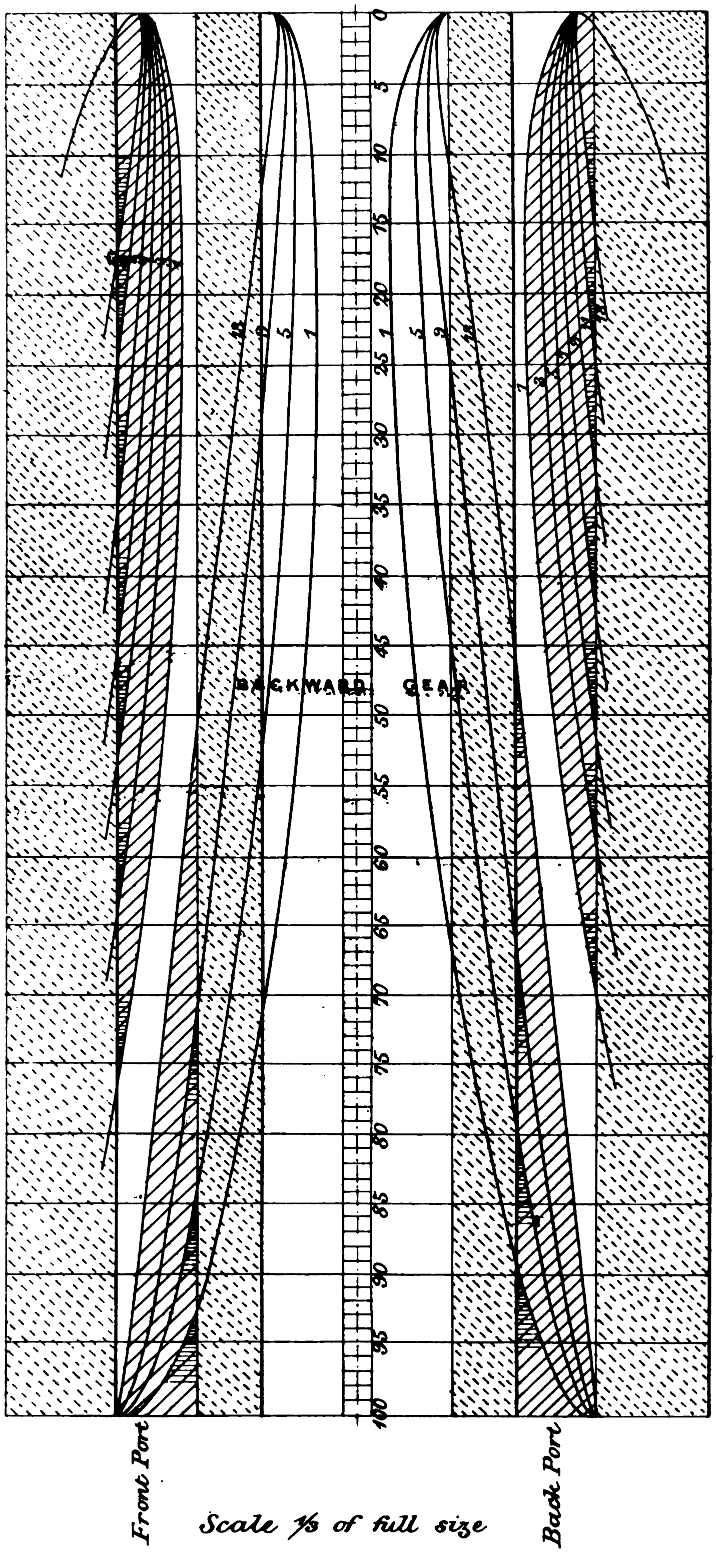
FOR THE G.I.P.R. G. BERKELY, ESQ. ENGINEER.





STROKE.

EAR.		
Leads		
.P.	B.P.	
4 f	¼ b	1
16	¼ f	2
16 f	5/16 b	3
8 b	5/16	4
8 b	5/16 f	5
8	5/16 f	6
8	⅜ b	7
8 f	⅜ b	8
8 f	⅜	9
8 f	⅜	10
8 f	⅜ f	11
f	⅜ f	12
8 f	⅜ f	13



Scale ⅓ of full size

N. P. Burgh. Direx

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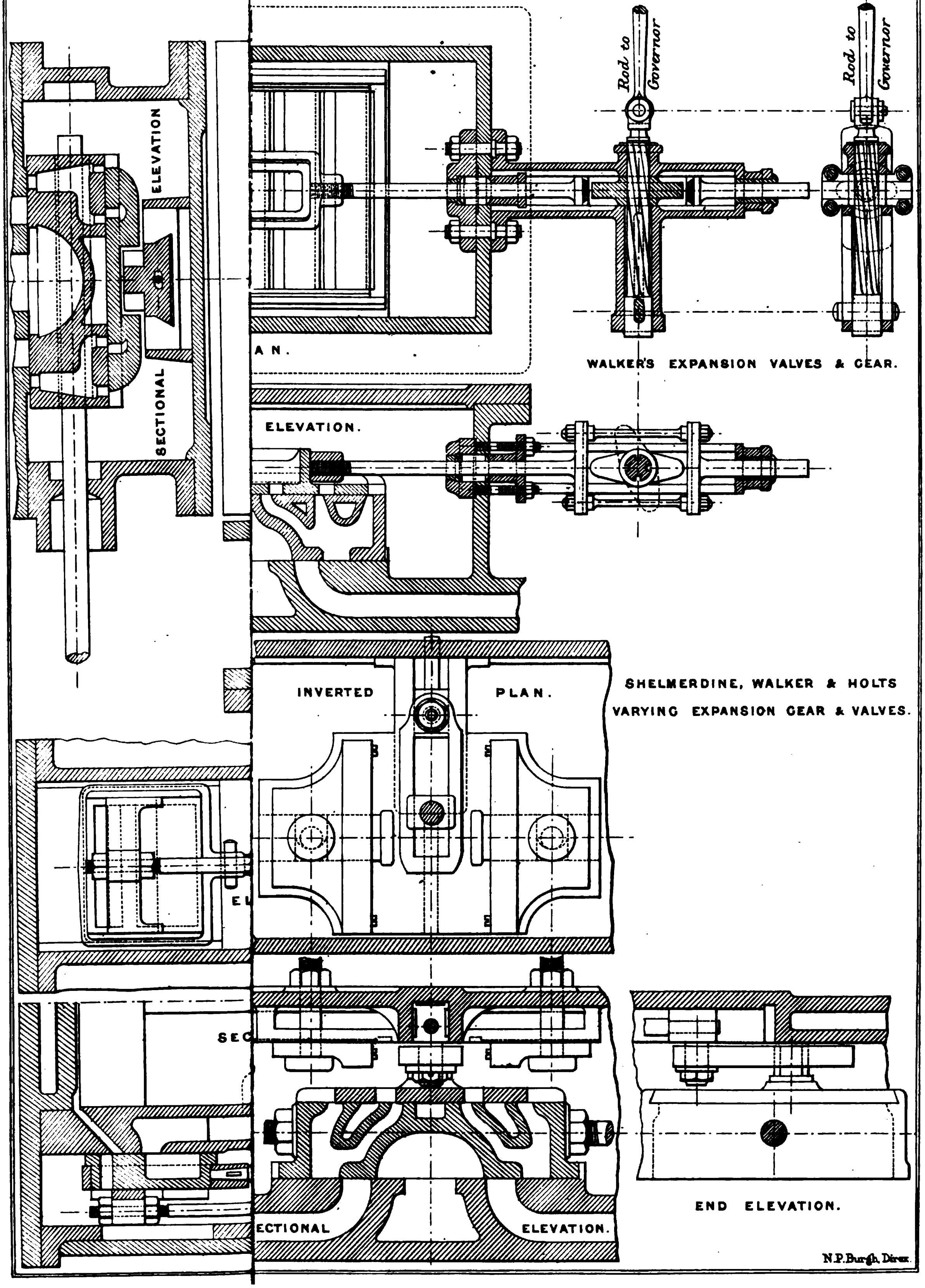
ARERNORS FOR STATIONARY ENGINES.

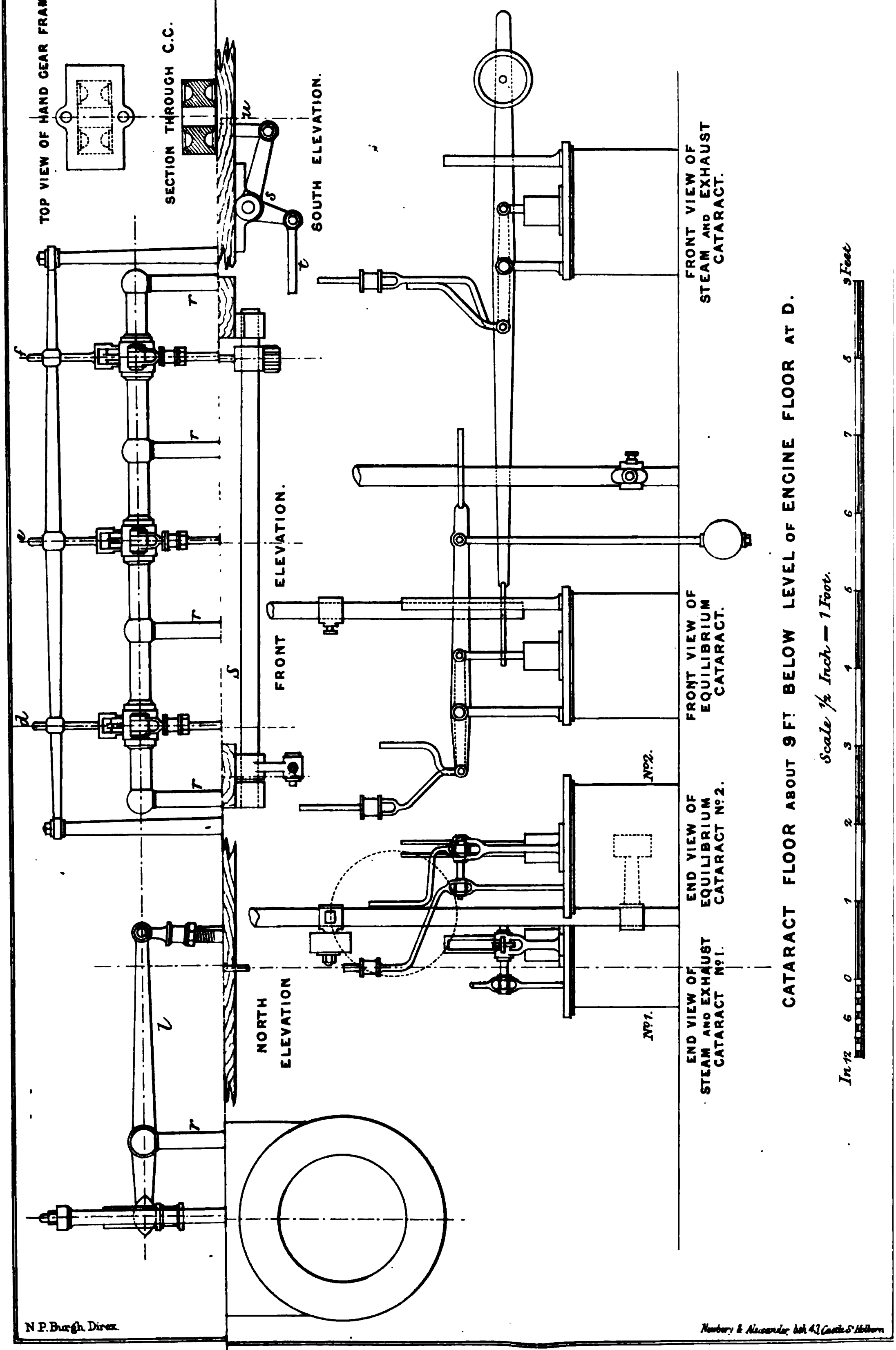


WALKER'S EXPANSION VALVES & GEAR.

SHELMERDINE, WALKER & HOLTS VARYING EXPANSION GEAR & VALVES.

N.P.Burgh Direx.

HAN HOWE, CLAY CROSS. FEBRUARY. 9TH 1862.


TOP VIEW OF HAND GEAR FRAME
SECTION THROUGH C.C.
SOUTH ELEVATION.
u
s
t
r
f
e
d
S
FRONT ELEVATION.
l
NORTH ELEVATION
FRONT VIEW OF STEAM AND EXHAUST CATARACT.
FRONT VIEW OF EQUILIBRIUM CATARACT.
END VIEW OF EQUILIBRIUM CATARACT No.2.
END VIEW OF STEAM AND EXHAUST CATARACT No.1.
No.2.
No.1.
In 12
6
0
1
2
3
4
5
6
7
8
9 Feet

CATARACT FLOOR ABOUT 9 FT. BELOW LEVEL OF ENGINE FLOOR AT D.

Scale ½ Inch — 1 Foot.

N.P. Burgh. Direx.

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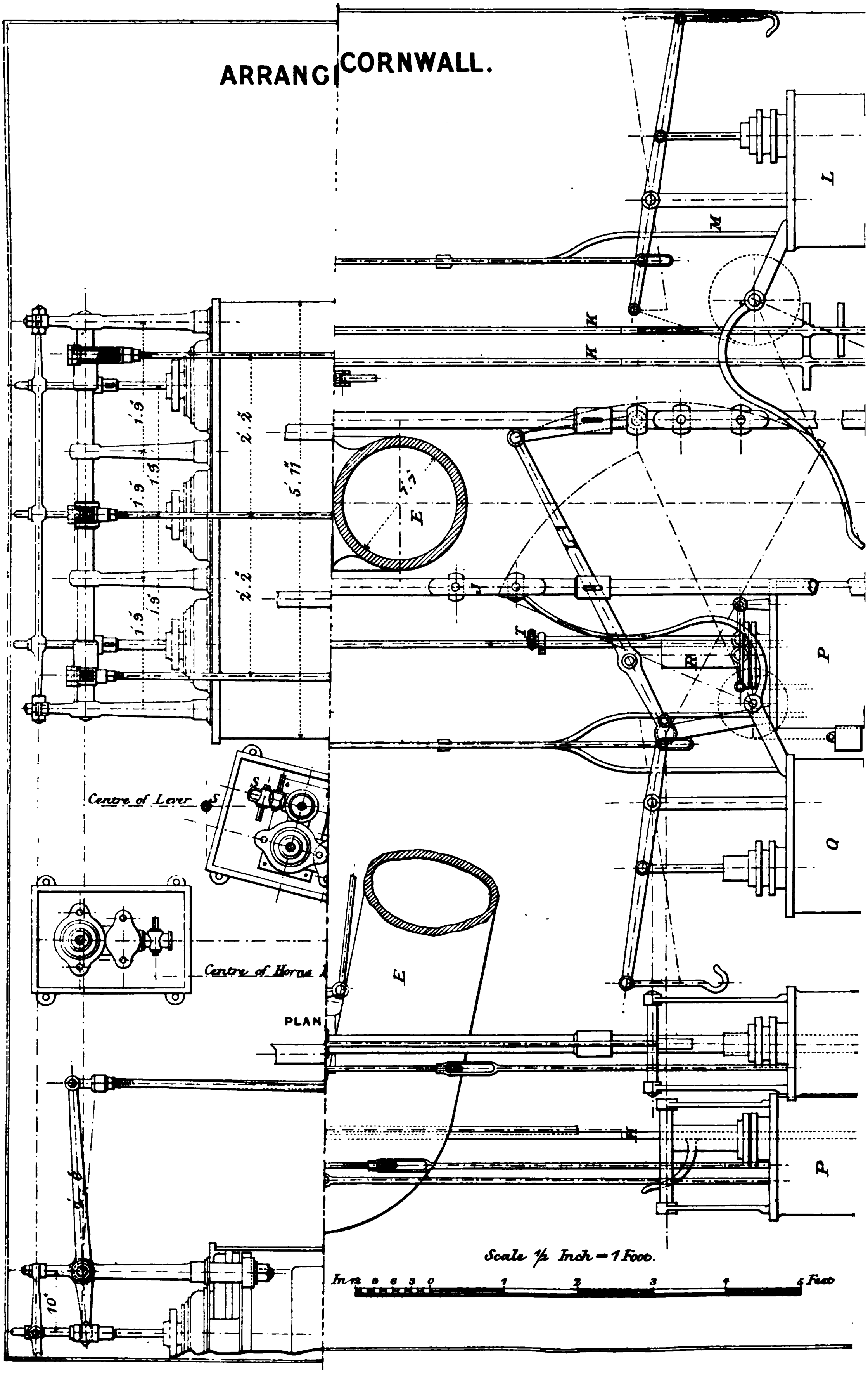
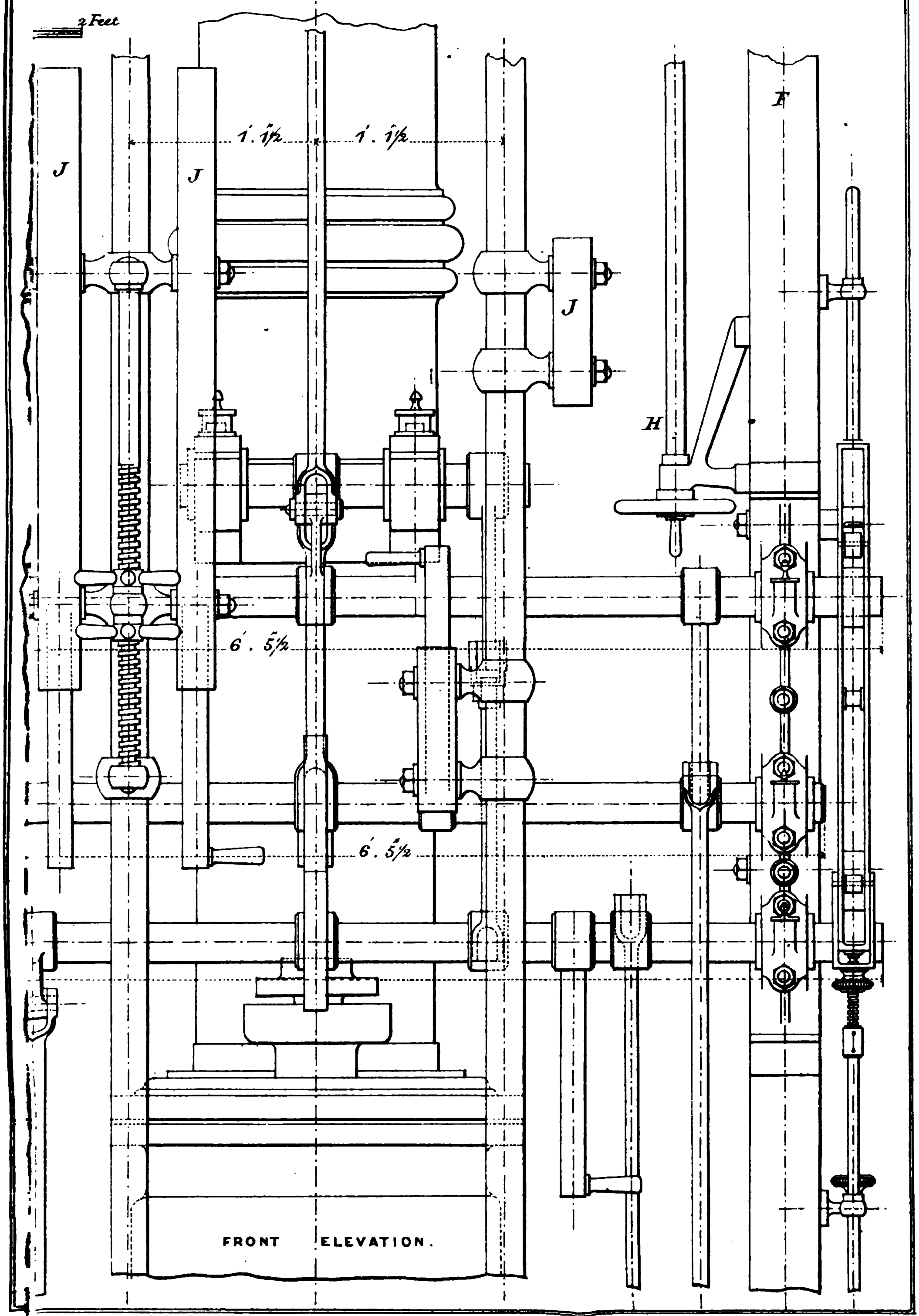
ARRANG CORNWALL.

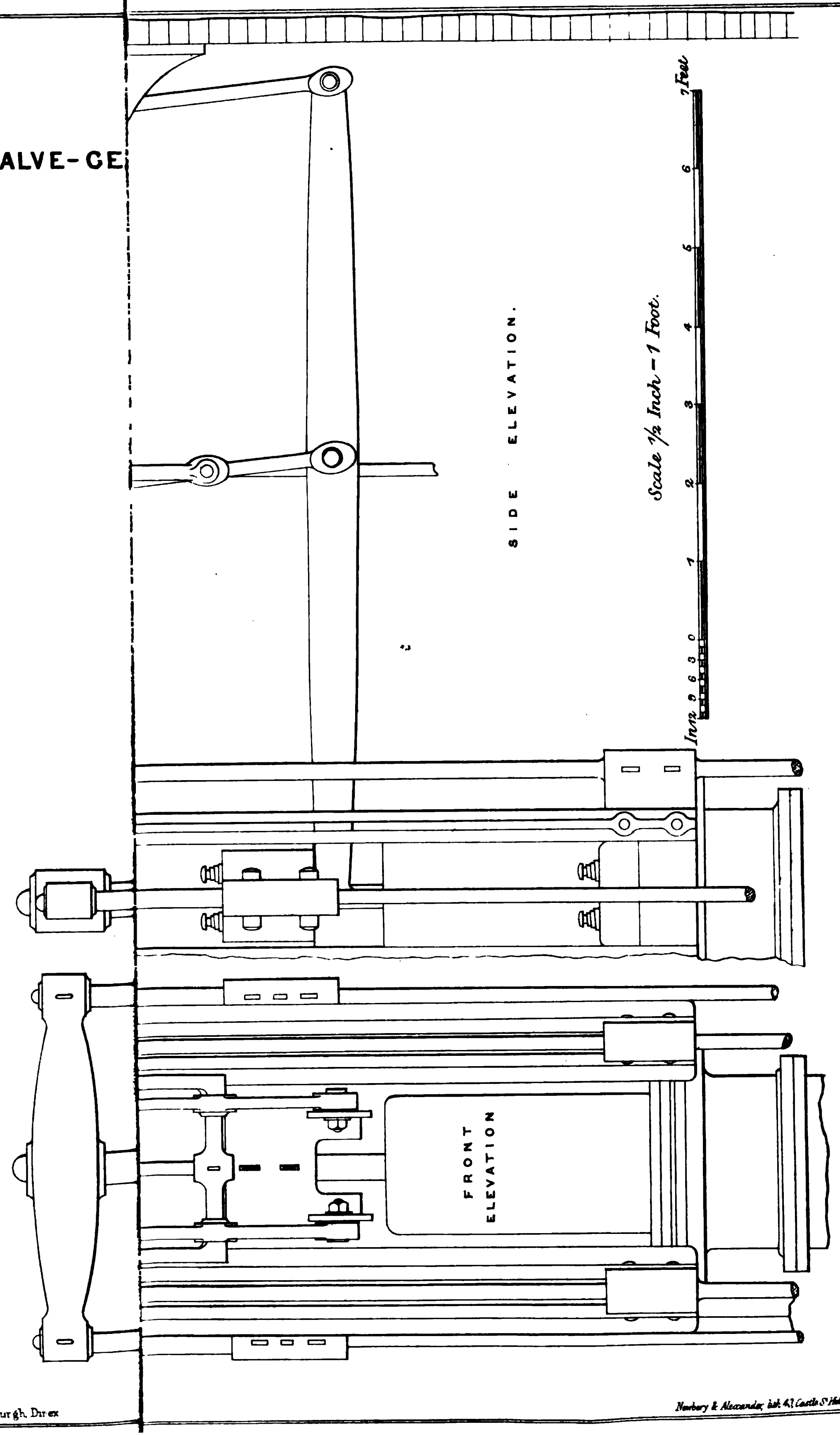


Srs HARVEY & Co HAYLE, CORNWALL.



FRONT ELEVATION.

VALVE-GE



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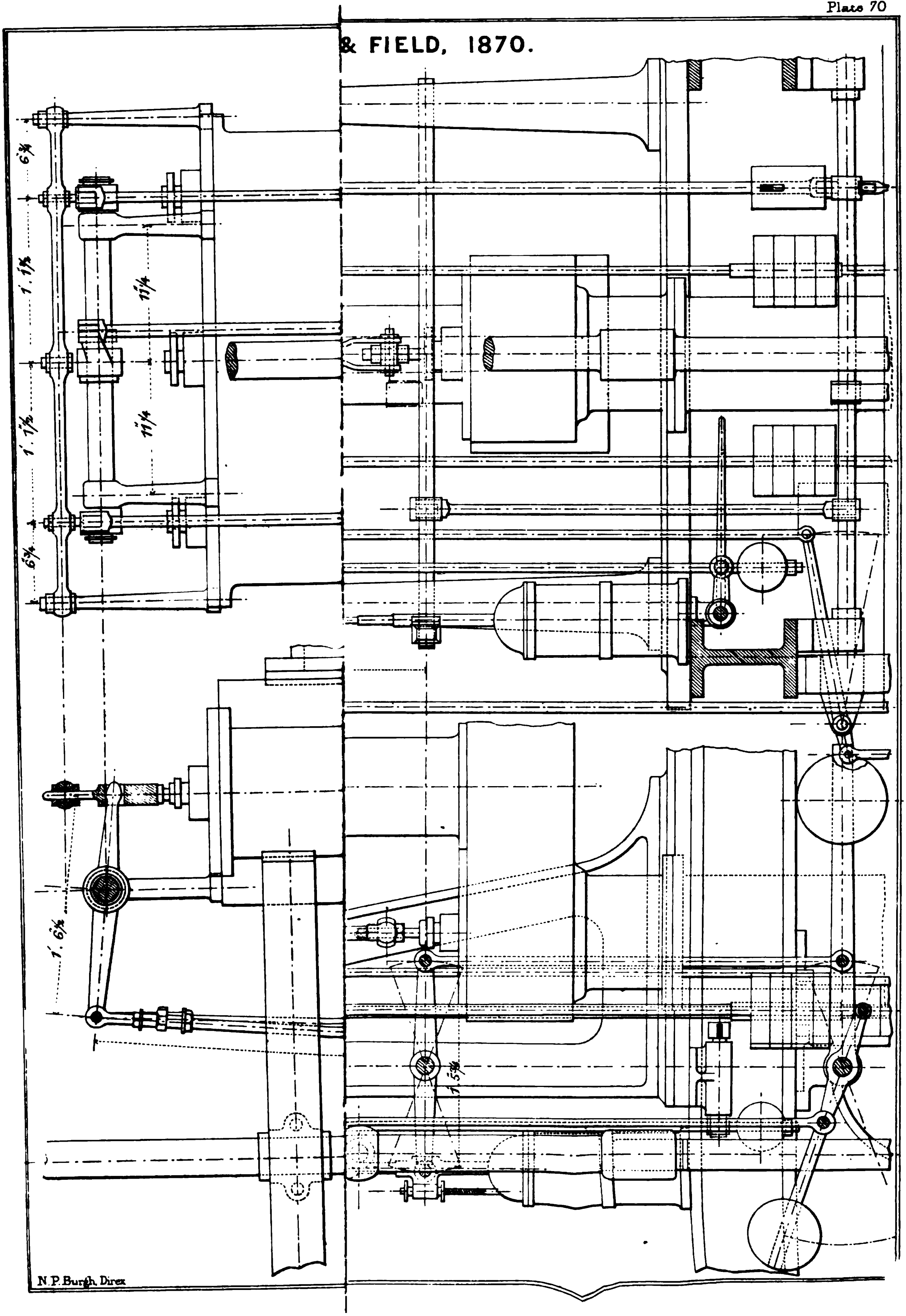
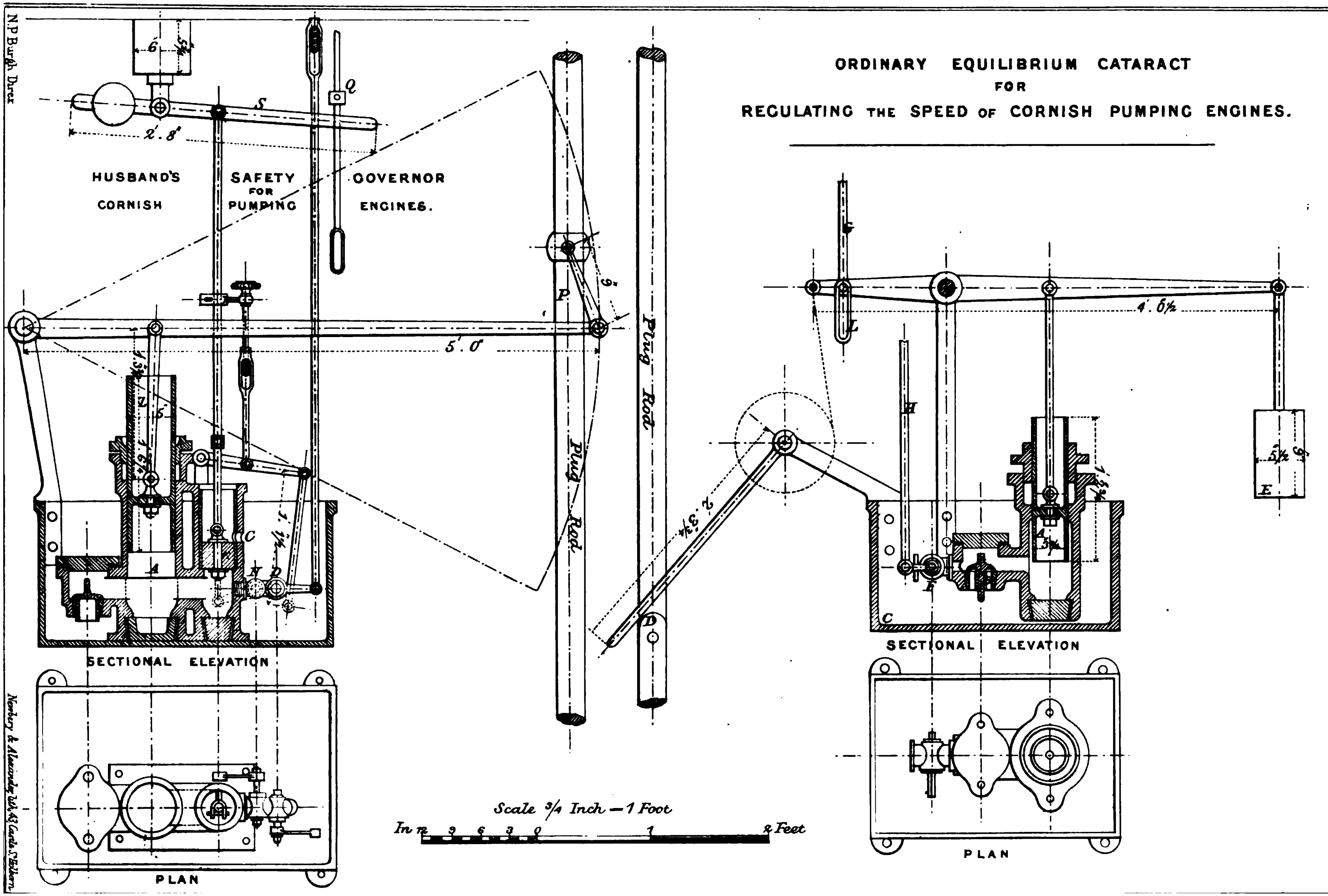
& FIELD, 1870.



ORDINARY EQUILIBRIUM CATARACT FOR REGULATING THE SPEED OF CORNISH PUMPING ENGINES.



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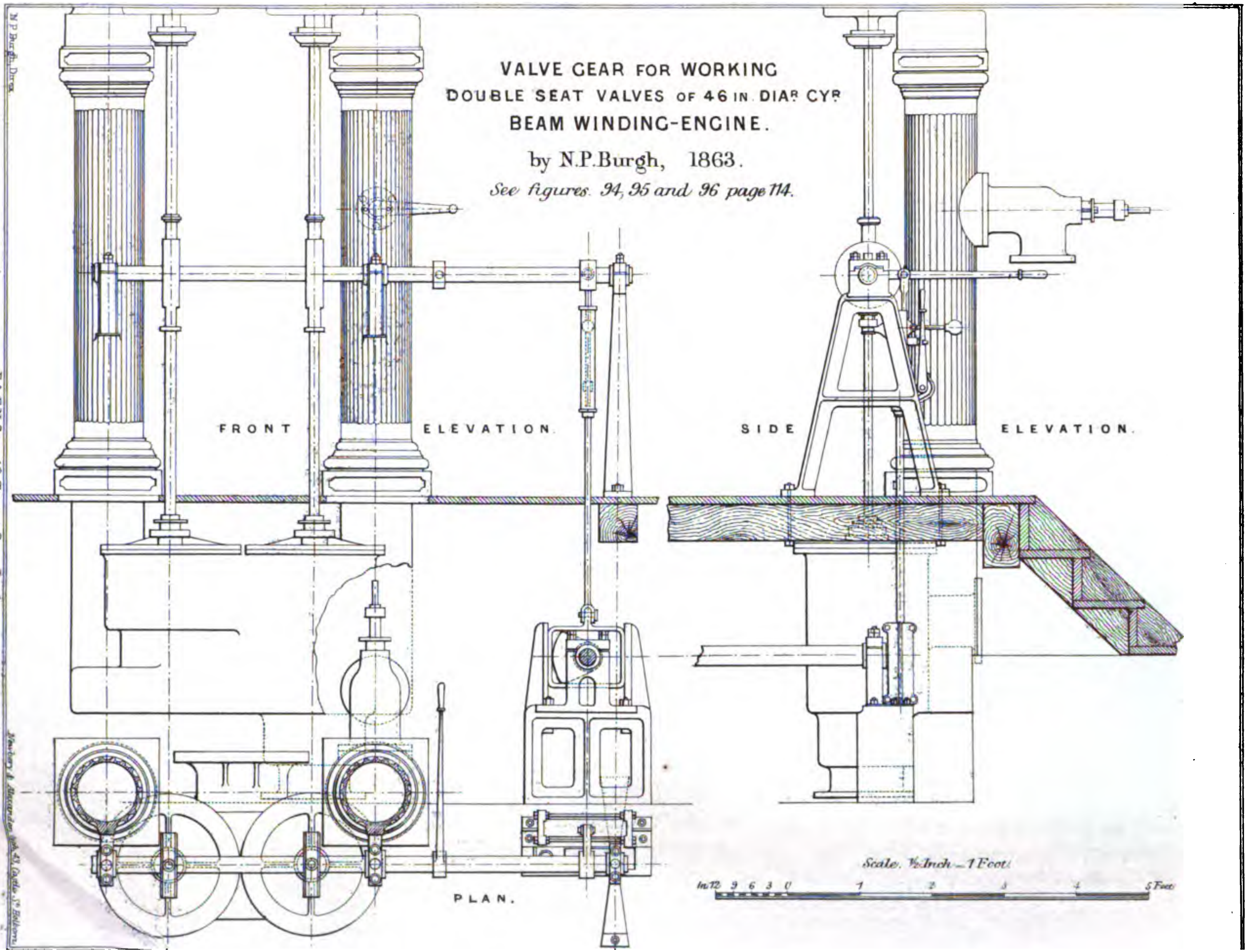
VALVE GEAR FOR WORKING DOUBLE SEAT VALVES OF 46 IN. DIAR CYR BEAM WINDING-ENGINE.

by N.P.Burgh, 1863.

See figures. 94, 95 and 96 page 114.



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